4.0 Development of Alternatives

This section develops five alternatives for mine water management. The alternatives were formulated by combining technologies identified in Section 3. The NCP provides that the primary goal of the FS is to ensure that appropriate remedial alternatives are developed and evaluated such that relevant information concerning the remedial action options can be presented to decision makers and an appropriate remedy selected. The development and evaluation of alternatives reflects the scope and complexity of the remedial actions under consideration and the site problems being addressed. EPA has relied on previous and recently collected information to develop and evaluate a range of alternative approaches consistent with NCP requirements and the RAOs for the Bunker Hill mine water.

4.1 Alternatives Assembly

The alternatives were assembled using the technologies for each of the six remedy components summarized in Table 3-3 for management of the AMD. The six remedy components are:

- AMD Mitigations
- AMD Collection
- AMD Conveyance
- AMD Storage
- AMD Treatment
- Sludge Management

The components are closely related, in that the type, size, or performance of one can influence the type, size, or performance of another. For example, mitigations are intended to reduce the quantity of AMD discharge from the Kellogg Tunnel. Reducing the discharge will reduce the amount of AMD needing to be collected, conveyed, stored, and treated, and likely the amount of sludge produced. A smaller discharge of AMD from the Kellogg Tunnel portal would require a smaller treatment plant. Because of these relationships, it is desirable to assemble alternatives that contain a range of mitigations and treatment plant sizes for comparison.

4.2 Alternatives Development

The relationship between the degree of mitigation implementation and treatment plant size is important for alternative development. Another important consideration is the amount of AMD storage needed for maintenance of the conveyance pipeline and treatment plant, unexpected treatment plant shutdowns, and unusually high Kellogg Tunnel flows. Treatment plant effluent concentrations must be considered because the TMDL discharge limit is metal-load-based, and because load (mass per time) is equal to flow rate (volume per time) times concentration.

4.2.1 TMDL Computer Model

4.2.1.1 TMDL Computer Model Overview

CH2M HILL developed a computer model using Microsoft Excel™ to evaluate the relationship between the TMDL for the CTP, mitigation measures (Kellogg Tunnel flow reductions), treatment (CTP size and effluent concentration), and AMD storage volumes. A detailed explanation of the input parameters, model logic, and assumptions used in the model is presented in Appendix F. Figure 4-1 presents an overview of the logic used in the model. An overview of the TMDL and how it was developed is provided in Section 2.6.2.1.

The model uses flow data for various WYs for which Kellogg Tunnel flow data are available, as described in the hydrologic evaluation document (CH2M HILL, 2000d). The five WYs with the highest Kellogg Tunnel flows (1973, 1974, 1981, 1982, and 1996) were primarily used in the model because these years are the most difficult of the historic data sets for TMDL achievement because of their high Kellogg Tunnel flows. Hydrographs for these years are shown in Figures 4-2 through 4-6.

The model requires the following input data:

- CTP capacity in gpm
- CTP effluent concentrations of total cadmium, lead, and zinc
- Mitigation effectiveness in terms of percent flow reduction for four Kellogg Tunnel flow ranges. Figure 2-15 in Section 2 shows these ranges with respect to historical Kellogg Tunnel flow hydrographs. The flow intervals listed below were used in the analysis:
  - KT <1,500 gpm (low to average flow conditions)
  - 1,500 gpm < KT < 2,500 gpm (medium to medium-high flow conditions)
  - 2,500 gpm < KT < 3,500 gpm (medium-high to high flow conditions)
  - KT > 3,500 gpm (high to very high flow conditions)

The basic model logic is conducted in four general steps (see Figure 4-1), with the rule that the TMDL cannot be exceeded on a daily basis.

Step 1: TMDLs are calculated on a daily basis, based on SFCdA River flow. The TMDL is converted to “allowable discharge” in gpm by dividing the TMDL by the CTP effluent concentrations input to the model. The minimum flow (gpm) is selected based on the minimum computed cadmium, lead, and zinc allowable discharge loads.

Step 2: Kellogg Tunnel discharge is compared to CTP capacity. AMD is either diverted to storage or treated. It is diverted to storage if the Kellogg Tunnel discharge is higher than CTP capacity. This type of storage is called “hydraulic storage” because it is needed as a result of the hydraulic capacity of the CTP. When the volume of AMD in storage is zero, Kellogg Tunnel flow may be less than CTP capacity because there is no stored AMD to augment the difference between CTP capacity and the Kellogg Tunnel flow rate.

Step 3: CTP discharge is compared to the allowable discharge calculated above. AMD is diverted to storage if the calculated CTP discharge load is greater than the allowable discharge load. This type of storage is called "TMDL storage" because it is needed as a result of CTP discharge limitations imposed by the allowable daily metal discharge load.

Step 4: The net change in storage is calculated and expressed as cumulative storage volume.

The model logic uses assumptions that could potentially be a source of error. First, the model assumes that CTP effluent concentrations are constant and do not fluctuate in response to changes in the flow or metal loads of the CTP influent. However, effluent concentrations are likely to vary to some degree, which can only be determined through operational experience. To account for this uncertainty, a range of CTP effluent concentrations can be evaluated. Second, the effectiveness of the mitigations for reducing flow out the Kellogg Tunnel is uncertain. The actual effectiveness of any mitigation won't be known until it is constructed and monitored. Therefore, a range of potential mitigation effectiveness can be evaluated using the model. For simplicity, the model uses percent Kellogg Tunnel flow reductions to assess mitigation effectiveness over the four Kellogg Tunnel flow ranges. Another assumption is that diversion to storage and pumping from storage can be adjusted to the nearest gpm. The actual diversion and pumping rates will depend on the capabilities of the system constructed. The model also assumes 100 percent efficiency in operating each of the system components.

The model output is displayed graphically in plots of storage required (defined as the total maximum storage required at any time during the WY for both hydraulic storage and TMDL storage) versus treatment plant size. The model output sheets (See Appendix F) list required hydraulic storage separately from required TMDL storage. The output graphs also show the volume of AMD remaining in storage at the end of a WY ("Remaining Storage").

4.2.1.2 Model Runs

Model runs were made to evaluate the effect of the following variables on TMDL achievement and storage requirements:

CTP Effluent Concentration. The model was used to evaluate TMDL achievement using the following anticipated CTP effluent concentrations based on the treatability testing described in Section 3.6.1:

- Cadmium = <0.70 μg/L
- Lead = <1.0 μg/L
- Zinc = <70 μg/L

CTP Capacity. CTP capacities between 1,500 and 7,000 gpm were evaluated using the model. This range covers the anticipated capacities based on the historical Kellogg Tunnel flow record.

Mitigation Effectiveness. The total volume of AMD storage required for either achievement of the TMDL or for hydraulic storage was evaluated using the model for different estimates of mitigation effectiveness. This was done by using estimated flow reduction percentages for the four Kellogg Tunnel flow ranges used in the model. Table 4-1 shows the modeled percent flow reductions.

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Greater estimates of mitigation flow reductions were used for higher Kellogg Tunnel flows because in general the mitigations are expected to be more effective diverting the Kellogg Tunnel flow “peaks” than the base flows. This is especially the case for the West Fork Milo Creek stream diversion because all the current flow from the West Fork Milo Basin is believed to enter the mine as described in Section 2. This diversion is expected to capture the flow in the stream and alluvium because it will be keyed into bedrock if possible, but it will not capture flow in the underlying fracture system that recharges the mine year-round.

4.2.1.3 Model Results

CTP Effluent Concentrations. Table 4-2 presents the maximum allowable CTP effluent flow rates at the anticipated CTP effluent concentrations for the four TMDL river flow conditions. The results indicate the discharge rate limiting metals are cadmium and zinc. For both cadmium and zinc the allowable effluent flow rate under 7Q10 discharge conditions is about 2,800 gpm. CTP effluent flow rates below about 2,800 gpm can be discharged without exceeding the allowable daily zinc and cadmium loads. It is apparent from Table 4-2 that the lead TMDL may not limit the CTP effluent flow rate at any river condition, since flows in excess of 11,000 gpm are not expected.

CTP Capacity and Mitigation Effectiveness. The maximum volume of AMD storage required for CTP capacities between 1,500 and 7,000 gpm was evaluated for the flow reduction percentages shown in Table 4-1 using the anticipated effluent concentrations. Higher Kellogg Tunnel flow reductions would allow use of a smaller CTP, less storage volume, and higher effluent concentrations. Figures 4-7 through 4-12 show plots of maximum storage volumes required, remaining AMD storage at the end of the WY, and CTP capacity for the percent mitigation effectiveness ranges shown in Table 4-1. Inspection of the figures shows that decreasing storage is required for smaller CTP capacities as more mitigation effectiveness is achieved. If no mitigations were implemented, as depicted by Figure 4-7, over 400 million gallons of storage would be needed for a 1,500 gpm CTP capacity, and a 7,000 gpm treatment capacity would be needed to eliminate the need for storage (maximum modeled KT flow was 6,700 gpm). The other extreme is depicted in Figure 4-12, which assumes highly effective mitigations. In this instance, about 30 million gallons of storage would be needed for a 1,500 gpm CTP, and a 2,000 gpm CTP would require no storage.

An important finding was that nearly all the storage was needed because the Kellogg Tunnel flow was higher than the CTP capacity (hydraulic storage), and very little storage was needed for TMDL achievement (TMDL storage). The most TMDL-required storage for all conditions modeled was 14.5 million gallons for water year 1973 with a 7,000 gpm capacity CTP and no mitigations. WY 1973 had the highest Kellogg Tunnel flows on record.

Although the specific amount of Kellogg Tunnel flow reduction as a result of the mitigations is unknown, the modeling results provide an estimate of flow reductions depending on assumed effectiveness. Table 4-3 lists the estimated Kellogg Tunnel peak flow, average flow, and average annual volume reductions for water years 1973, 1974, 1981, 1982, and 1996 using the percent flow range reduction approach described in Section 4.2.1.2. Treatment lime consumption and sludge production are expected to be reduced linearly with respect to flow volume reductions, as supported by the findings presented in the technical memorandum in Appendix B.

The application of one set of these flow reductions to WY 1973, The WY with the highest Kellogg Tunnel flow on record, is shown in Figure 4-13. The figure demonstrates the resulting Kellogg Tunnel flow hydrograph if a mitigation were in place during WY 1973 with a flow reduction effectiveness of 15 percent, 30 percent, 50 percent and 80 percent. The peak flows are reduced significantly, while base flows are only slightly reduced.

4.2.2 Considerations for Alternative Development

The most important consideration for alternative development is the quantity and quality of AMD that must be managed. This factor affects every component of an alternative, from mitigations to treatment sludge management. The following sections discuss this and other considerations in more detail.

4.2.2.1 AMD Quantity and Quality

AMD Quantity. The quantity of AMD to be managed in the future is uncertain. Historically, the flow from the Kellogg Tunnel portal has varied significantly, as depicted in Figure 2-15. The highest estimated flow is about 6,700 gpm, which occurred in December 1972 (this flow was recorded as 6,000+ gpm, and the 6,700 gpm is an estimate based on the shape of the hydrograph). In more recent times the highest flow was about 4,000 gpm, which occurred in 1996.

The quantity of Kellogg Tunnel flow depends on how much water is infiltrating into the mine workings. Based on the site conceptual model, high flows are associated with snowmelt and rain-on-snow events that rapidly increase surface flows above the workings, leading to higher infiltration. The historical flow record shows that these events can be sudden, with Kellogg Tunnel flows increasing many thousands of gpm in a few days. The peaks usually involve only a few days but the falling limb of the hydrograph can take a few weeks. The historical peak flows indicate movement of water rapidly from a surface source (probably stream flow) through the upper workings, because the response is too sudden for groundwater flow systems in undisturbed rock.

Reducing the rapid stream flow infiltration, particularly from the West Fork Milo Basin, may significantly reduce peak Kellogg Tunnel flows. Reducing recharge to bedrock fractures and faults that intercept mine workings should reduce base flows. Sealing the Small Hopes Drift below Milo Creek and the Inez Shaft below Deadwood Creek will guard against the streams eroding direct flow paths into the mine.

AMD Quality. The quality of the Kellogg Tunnel discharge has been studied extensively, as summarized in Section 2. Comparison of Kellogg Tunnel discharge chemistry data from the 1970s, 1980s, and 1990s shows variability, with metal concentrations varying sometimes rapidly and also seasonally. Rapid variations can be caused by mining-related water management such as pumping rates, direction of flow paths, ditch cleaning, and drilling operations. Rapid variations can also be caused by spring snowmelt and infiltration from surface streams, which results in more water coming from one area of the mine having different chemistry than other areas.

Seasonal AMD quality variations occur as a result of spring snowmelt. In general, the Kellogg Tunnel discharge quality deteriorates during the higher spring flows because of flushing of accumulated metal salts along mine water flow paths. The result is much higher

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metal loads needing treatment in the spring because of these higher flows and higher concentrations.

The majority of the seasonal increase in Kellogg Tunnel metal loads comes from the Flood-Stanly Ore Body. Reducing seasonal recharge through the Flood-Stanly Ore Body will likely decrease the Kellogg Tunnel treatment load by reducing the flushing of accumulated metal salts, as described in the technical memorandum in Appendix B. This memorandum also evaluated the potential for large buildup of metal salts in the absence of periodic flushing, and the possibility that very high metal loads would be released when a flushing event did occur. While this is a possibility, the technical team concluded that this release mechanism is unlikely. Large metal salt accumulations have not been observed in accessible areas of the Flood-Stanly Ore Body; a hysteresis effect has also not been observed in plots of metal concentration versus flow rate in monitoring stations downstream of the Flood-Stanly Ore Body (see Appendix B). If large salt accumulation had occurred, then a hysteresis affect should be present where the rising limb of the monitoring station hydrographs would carry more metal load than the recessional limb. However, this has not been observed.

Although large salt accumulations are not expected if seasonal flushing is reduced by mitigations, accumulation should be monitored as part of implementing mitigations. Contingency measures could be taken to either store or treat very high metal loads in the event of a mine flood, mitigation failure, or high discharge event that would flush accumulated acid and metal salts from the mine.

4.2.2.2 Mitigation Effectiveness

Mitigations constructed to reduce recharge to the mine are expected to reduce average and peak Kellogg Tunnel flows requiring treatment. Mitigations that reduce recharge through the Flood-Stanly Ore Body are expected to reduce the metal load requiring treatment, which will reduce treatment cost and sludge generation. Mitigations in West Fork Milo Basin are expected to be the most effective for reducing peak Kellogg Tunnel flows and metal loads. Because peak Kellogg Tunnel flows are associated with rapid infiltration through streambeds, particularly in the West Fork Milo Basin, it is believed that diversion of West Fork Milo Basin flows away from the Guy Cave Area will significantly reduce peak Kellogg Tunnel flows and associated acid and metal loads. The effectiveness in reducing Kellogg Tunnel flows is expected to be higher for peak flows than base flows.

The goal of reducing infiltration to the mine is to reduce the quantity of AMD and the resulting acid and metal loads needing to be treated. Smaller Kellogg Tunnel flows would allow construction of smaller treatment facilities. Reducing the recharge through the Flood-Stanly Ore Body should reduce the acid and metal load, and hence the amount of lime used and sludge generated. Reduction of peak Kellogg Tunnel AMD flows also reduces the strain placed on AMD collection, conveyance, storage, and treatment facilities, because smaller flows are more readily managed than larger flows. This reduces the risk of failure of any of these components, and also the consequence of untreated AMD discharging to Bunker Creek, because the AMD flow rate is lower.

Because of the complexity of mine recharge, the effectiveness of mitigation measures will not be known until they are constructed and monitored. Even when constructed, their effectiveness may not be known for a number of years because it may take many spring runoff seasons to accumulate sufficient information to assess long-term trends. Although it is possible to reduce the size of required treatment facilities based on mitigation effectiveness, this approach assumes some risk. A mine flood, mitigation failure, or extreme precipitation event could generate Kellogg Tunnel flows or acid and metal loads that would exceed the constructed treatment capacity. Based on historical flow data, higher than expected flows coming from the mine are possible. Consequently, the risk of such events will remain even after mitigations are constructed. Use of AMD storage would reduce this risk because the excess flows could be stored for subsequent treatment.

In summary, implementation of mitigation measures could be done in conjunction with close effectiveness monitoring to reduce the risk of failure, and with contingency measures to store unexpected and excessive AMD flows. The costs and benefits associated with constructing, operating, and monitoring the mitigations could be tracked to evaluate cost-effectiveness. Phasing the implementation of mitigations and treatment plant capacity could be effective for managing risk and cost. Mitigation effectiveness monitoring and evaluation required to support a phased implementation approach is described in Section 4.3.3.

4.2.2.3 Mine Water Collection

Reducing recharge to the mine, and hence Kellogg Tunnel flow, will reduce the volume of AMD needed to be collected and managed within the mine. AMD is collected within the mine using the ditches along the drifts to collect gravity drainage, and the pump system in No. 2 Shaft to collect mine pool water, as described in Section 2. All flows are conveyed out of the mine via the Kellogg Tunnel.

Successful collection of the gravity flow from the workings above 9 Level and conveyance out the Kellogg Tunnel of the pumped mine pool water relies on the continued operation of the ditch system. This requires considerable maintenance because of ongoing deposition of iron oxy-hydroxides (yellow boy) and other debris. This material must be shoveled out to maintain ditch capacity; otherwise, the water overruns the ditch and flows along the drifts themselves, which damages the railway track, timbers, and other infrastructure.

The in-mine flow paths are fairly well known on 9 and 5 Levels on the east side of the mine, but little is known about flow in other locations that have not been recently mined, many of which are inaccessible. The lack of inspection and maintenance will gradually lead to deterioration of the workings and blockage that impounds AMD, which will lead to less predictable flow on 9 Level. It is possible that floods resulting from the collapse of in-mine AMD impoundments will become more common.

The Kellogg Tunnel ditch inside the portal has limited capacity. The specific capacity is unknown, but likely below the 7,000 gpm capacity of the concrete ditch outside the portal and the AMD conveyance pipeline. This could result in excess AMD not being collected in the concrete ditch. If this occurred and the excess was not diverted back into the concrete channel, it would run through the mine yard and down the hill to Bunker Creek, recontaminating properties that have already been cleaned up. Some AMD may drain into the storm water system that discharges to Bunker Creek. Reduction of mine infiltration is expected to reduce the Kellogg Tunnel flows, which will help ensure that all the AMD will be collected at the portal. Contingency measures or modifications at the portal are needed for collection of Kellogg Tunnel portal discharge in excess of the ditch's carrying capacity.

4.2.2.4 Mine Water Conveyance

The Kellogg Tunnel portal ditch discharges into a concrete channel, which carries the AMD through a Parshall flume for flow measurement and recording, and then into a buried pipeline that conveys it into the lined pond for storage prior to treatment. The concrete ditch and pipeline have a capacity of about 7,000 gpm. The old mine water pipeline, which is connected to the new pipeline downstream of the concrete ditch via an overflow manhole, is limited to an unknown amount of less than about 1,400 gpm based on flow observations during the spring of 1999, when the pipeline failed to convey all the mine water.

Currently, all Kellogg Tunnel flow is conveyed to the lined pond, where a pump station pumps it to the treatment plant. This results in the deposition of considerable sediment and muck in the pond. Direct flow to the treatment plant is needed to prevent continued deposition in the lined pond that is costly to remove and diminishes storage capacity. Trash racks and sediment systems may be needed prior to the CTP to remove material that could plug or harm process equipment. The existing mine water conveyance system with a new tee segment for flow directly to the CTP is included in each of the alternatives evaluated.

4.2.2.5 Mine Water Storage

AMD storage is needed for conveyance system and treatment plant shutdowns, when the Kellogg Tunnel portal discharge rate is higher than the treatment plant capacity, and if the discharge rate became limited by TMDL discharge allocations. Storage options were described in Section 3.5. The amount of storage needed can be reduced by mitigations to reduce recharge to the mine and by constructing more capacity and reliability in the treatment plant. Contingency storage will always be needed when the treatment plant is shut down or inoperative. Providing more backup and redundant treatment systems at the treatment plant can reduce contingency storage.

Each alternative includes the use of the existing lined pond (7 million gallons) and in-mine storage. The lined pond will be used for short durations and scheduled CTP shutdowns. In-mine storage will be used for longer-duration shutdowns and contingency storage for flows or treatment loads in excess of the CTP's capacity, which are expected to be infrequent. In-mine storage is planned for this purpose; that is, the approximately 20 million gallons below 11 Level and the approximately 190 million gallons from the floor of 11 Level up to the floor of 10 Level at the No. 2 Shaft.

Use of in-mine storage above 11 Level will have some impact on mining operations and mine infrastructure. Infrequent level flooding will require extra maintenance for the mineshafts, hoists, and drifts, because of the effects of the rising and falling water elevations.

4.2.2.6 Mine Water Treatment

As described in more detail in Section 3.6 and in Appendix E, the CTP requires significant improvements in order to achieve the TMDL, reduce sludge production, improve reliability, and increase cost efficiency. The CTP Master Plan in Appendix E also describes the existing condition of the CTP and its present shortcomings. It describes upgrades in terms of three phases: Phase 1 are upgrades for a capacity of 2,500 gpm, Phase 2 are additional upgrades needed for a capacity of 5,000 gpm, and Phase 3 are upgrades needed if mechanical sludge dewatering were implemented. The CTP Master Plan also provides process flow diagrams and describes how the plant can remain in operation as much as possible during upgrades. The most significant change required to achieve the TMDL is the addition of tri-media pressure filters for removal of suspended solids and associated metal from the effluent. These filters will also allow the plant to be operated in the HDS mode, which is expected to reduce the annual sludge volume to about one half to one third of the present volume.

4.2.2.7 Sludge Management

As described in Section 3, four sludge management options will be evaluated for each alternative. The options are:

- Option A: Disposal of raw sludge in onsite sludge disposal beds located on the CIA that both dewater and permanently store the sludge
- Option B: Mechanical sludge dewatering and disposal of dry sludge in an offsite landfill
- Option C: Disposal of raw sludge in onsite sludge disposal beds located above the smelter closure area
- Option D: Sludge drying using sludge drying beds on the CIA and annual excavation and disposal of dry sludge in an onsite landfill located above the smelter closure area.

4.2.2.8 Performance Monitoring

Monitoring the performance of any remedial action is required to determine if it is meeting the remedial action objectives. Performance monitoring is included in each of the alternatives.

4.3 Remedial Alternatives

This section describes the remedial alternatives assembled from the above components and considerations for management of the Bunker Hill mine water. The NCP, in 40 CFR 300.430(e)(7), specifies three criteria that were used to guide the development of remedial alternatives:

- **Effectiveness—**This criterion focuses on the degree to which an alternative reduces contaminant toxicity, mobility, or volume through treatment; minimizes residual risks and affords long-term protection; complies with ARARs; minimizes short-term impacts; and how quickly it achieves protection. Alternatives providing significantly less effectiveness than other more promising alternatives may be eliminated. Alternatives that do not provide adequate protection of human health and the environment shall be eliminated from further consideration.
- **Implementability—**This criterion focuses on the technical feasibility and availability of the technologies that each alternative would employ, and the administrative feasibility of implementing the alternative. Alternatives that are technically or administratively infeasible or that would require equipment, specialists, or facilities not available within a reasonable time may be eliminated from further consideration.

- **Cost**—The cost of construction and any long-term costs to operate and maintain the alternatives were considered. A technically viable alternative with total costs well in excess of other viable alternatives can be screened out based on the cost factor alone. Professional judgment for such a screening is essential because the capital and operating cost estimates are commonly based on limited information.

EPA has developed detailed aspects and key components of the alternatives by an iterative process of data acquisition and evaluation. The development of alternatives based on this effort has led to early elimination of some approaches and more detailed development of others. The remedial alternatives provide a range of approaches for managing the Bunker Hill mine water. The primary difference between the alternatives is the degree to which AMD mitigations and treatment capacity are implemented. They include a No Further Action alternative (Alternative 1), an alternative consisting of a larger treatment plant but no AMD mitigations (Alternative 2), alternatives that use a phased approach for implementing AMD mitigations and treatment capacity (Alternatives 3 and 4), and one using smaller treatment capacity and all the AMD mitigations carried through technology screening (Alternative 5).

All of the following alternatives are carried forward into detailed analysis. All are implementable; all, except for Alternative 1 (No Further Action alternative), are considered effective; and none are considered too cost-excessive compared to the others. In EPA's judgment, the specific detailed alternatives presented below (with the exception of Alternative 1) represent the most appropriate approaches to control, reduce, or eliminate the risks to human health and the environment posed by the Bunker Hill mine water. The following alternatives are described with respect to their major components to facilitate comparison. Table 4-4 provides a comparative summary.

4.3.1 Alternative 1—No Further Action

The No Further Action alternative, Alternative 1, was developed and evaluated as required by the NCP in 40 CFR 300.430(e)(6). With respect to evaluating the alternative's potential for meeting the remedial action objectives for the Bunker Hill mine water, the no action alternative should be considered as "no further action." The no action alternative is commonly used as a baseline alternative against which other alternatives are judged. As the name implies, this alternative does not include any additional remediation activities or improvements. The existing mine water management approaches and systems would continue to be used until the existing sludge disposal area is full, which is estimated to be 3 to 5 years. At that time the CTP will be shut down, because it cannot operate without sludge disposal. This would result in the discharge of untreated AMD into Bunker Creek. All other current mine water management activities would also cease, because there would be no need to operate them. The exception may be AMD collection within the mine, but only if it was done unilaterally by the mine owner for mining operations.

4.3.1.1 AMD Mitigations

No mitigations for reducing water infiltration to the mine would be constructed under this alternative.

4.3.1.2 AMD Collection

There would be no changes to the existing AMD collection system until the CTP is shut down. At that time, AMD collection within the mine would occur only if done unilaterally by the mine owner for mining operations.

4.3.1.3 AMD Conveyance

There would be no changes to the existing AMD conveyance system. It would not be maintained after the CTP is shut down. The mine water would probably continue to flow into the lined pond, and then out the overflow into Bunker Creek.

4.3.1.4 AMD Storage

The existing 7-million-gallon lined pond would continue to be used until the CTP is shut down, at which time it would be abandoned.

4.3.1.5 AMD Treatment

No treatment plant upgrades or repairs would occur for this alternative. Plant failures resulting from aging equipment would be expected to occur more frequently, possibly leading to a CTP failure prior to the CTP being shut down when the sludge disposal capacity is exhausted.

4.3.1.6 Sludge Management

The treatment sludge is currently disposed of on top of the CIA in the unlined sludge impoundment. The estimated sludge accumulation rate is 15,000 to 18,000 cubic yards per year. This would continue until no capacity remained, estimated to be 3 to 5 years from now, depending on mine water flows and sludge generation rates. No additional sludge disposal capacity would be constructed once the existing capacity is consumed. Without additional sludge disposal capacity, the CTP would need to be shut down because it would not be able to operate.

4.3.1.7 Performance Monitoring

The existing monitoring program would continue until the CTP is shut down, at which time all monitoring would cease. The existing monitoring consists of monitoring at the Kellogg Tunnel and CTP. At the Kellogg Tunnel, this consists of continuous flow measurements and periodic (weekly or bi-weekly) samples collected for pH, TSS, and total cadmium, lead, and zinc. The current CTP monitoring consists of flow measurements and daily samples for pH, TSS, and total cadmium, lead, and zinc.

4.3.1.8 Alternative 1 Summary

Table 4-5 summarizes the components of Alternative 1, the No Further Action alternative.

4.3.2 Alternative 2—Treatment Only

Alternative 2 is termed the "Treatment Only" alternative because it would update and improve the treatment plant but would not include any mitigations for reducing infiltration to the mine and the volume of AMD from the Kellogg Tunnel. The treatment plant would be sized at 5,000 gpm, which is considered large enough to treat all Kellogg Tunnel flows

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except for the infrequent very high peak flows. These peak flows would be stored either in the lined pond or in the mine for later extraction and treatment.

4.3.2.1 AMD Mitigations

No mitigations for reducing water infiltration to the mine would be constructed under this alternative.

4.3.2.2 AMD Collection

There would be no changes to the existing AMD collection system.

4.3.2.3 AMD Conveyance

The existing conveyance system would be used, and an additional pipeline section (20-inch HDPE) would be added to allow direct flow of AMD to the treatment plant rather than to the lined pond. This would reduce sedimentation and cleaning of the lined pond, and would reduce the costs of operating the lined pond pump station.

4.3.2.4 AMD Storage

The existing 7-million-gallon lined pond would continue to be used for routine storage needs. The existing in-mine storage system would be used for larger storage and contingency needs. The existing diversion system to pump from the gravity ditches into the mine pool (about 1,050 gpm capacity) would be used if the Kellogg Tunnel discharge had to be reduced more than shutting off the mine pool pumping system would achieve (about 700 gpm capacity). The total capacity for in-mine storage is about 1,750 gpm. The largest recorded flow from the mine occurred in December 1972 and was estimated at about 6,700 gpm. This flow could be managed by storing 1,700 gpm and by treating 5,000 gpm. The existing mine pool extraction system would be used to remove stored water for treatment once the flows subsided.

Flows in excess of 5,000 gpm are expected to be very infrequent and have a short duration based on the historical data. Referring to Figure 2-15, which lists Kellogg Tunnel hydrographs for 16 years, it can be seen that 5,000 gpm was exceeded five times. Four of these times were during the 1973 WY, and the fifth was during the 1974 WY. Table 2-1 lists the estimated Kellogg Tunnel flow return intervals. A flow in excess of 5,000 gpm has an estimated return interval of about 13 years, with a probability of occurrence in any year of about 8 percent.

4.3.2.5 AMD Treatment

The CTP would be upgraded to a 5,000-gpm capacity with tri-media filters. For Alternative 2 the plant capacity would be increased to 5,000 gpm in one upgrade. If mechanical sludge dewatering is selected, it would be included with the upgrade.

4.3.2.6 Sludge Management

One of the following four sludge management options would be used:

Option A: Disposal of raw sludge in onsite sludge disposal beds located on the CIA that both dewater and permanently store the sludge

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Option B: Mechanical sludge dewatering and disposal of dry sludge in an offsite landfill

Option C: Disposal of raw sludge in onsite sludge disposal beds located above the smelter closure area

Option D: Sludge drying using sludge drying beds on the CIA and annual excavation and disposal of dry sludge in an onsite landfill located above the smelter closure area

4.3.2.7 Performance Monitoring

Monitoring would be conducted at the Kellogg Tunnel portal and at the CTP effluent flow to Bunker Creek. The Kellogg Tunnel portal monitoring is expected to include continuous flow recording and periodic (weekly or bi-weekly) samples for pH, TSS, lime demand/solids formed, and total cadmium, lead, and zinc analysis. The CTP effluent flow would be monitored, which is expected to consist of daily sampling for pH, TSS, and total metals. Additional treatment process control monitoring would be conducted, such as treatment setpoint pH and effluent turbidity.

4.3.2.8 Alternative 2 Summary

Table 4-6 summarizes the components of Alternative 2, the Treatment Only alternative.

4.3.3 Alternative 3—Phased Mitigations/Treatment

Alternative 3 would phase the implementation of mitigations and treatment plant capacity based on monitoring results. An initial set of mitigations would be implemented and an initial CTP capacity would be constructed. Up to 10 years of performance monitoring would be reviewed to determine if the initial mitigations and treatment plant capacity were sufficient, or if more were needed. A decision process consisting of data analysis, conceptual model refinement, assessment of mitigation effectiveness, and cost/benefit analysis would be used to evaluate remedy performance, and to select subsequent actions if warranted.

4.3.3.1 AMD Mitigations

The AMD mitigations that would be implemented initially would be the West Fork Milo Creek Diversion, rehabilitation of the Phil Sheridan diversion system, and plugging of the known in-mine drill holes that are discharging water. These mitigations are believed to have the highest potential for reducing recharge through the Flood-Stanly Ore Body and mine water flow out the Kellogg Tunnel. Additional mitigations that could be constructed later are those listed in Table 3-3 in Section 3 of this report, and possibly other mitigations not identified to date.

4.3.3.2 AMD Collection

The existing gravity drainage system would be used, but the mine pool pumping system in No. 2 Shaft would be replaced with two 700-gpm vertical turbine pumps. These new pumps would increase system reliability and provide quicker extraction of stored mine water.

4.3.3.3 AMD Conveyance

The existing conveyance system would be used, and an additional pipeline section (20-inch HDPE) would be added to allow direct flow of AMD to the treatment plant rather than to the lined pond. This would reduce sedimentation and cleaning of the lined pond.

4.3.3.4 AMD Storage

The existing 7-million-gallon lined pond would continue to be used for routine storage needs. The existing in-mine storage volume from about 30 feet below 11 Level and above would be used for larger storage and contingency needs. The diversion systems into the pool would be upgraded for gravity flow.

4.3.3.5 AMD Treatment

The CTP would initially be upgraded to a 2,500-gpm treatment and filtration capacity, which could be sufficient after the initial mitigations are constructed. This means that the reactor residence times and filter throughput rates would be optimally sized for a 2,500-gpm peak flow. The hydraulic throughput and lime feed capacity would be 5,000 gpm to provide redundancy, and also as a contingency measure for higher-than-expected Kellogg Tunnel flows. If additional CTP capacity is needed later, a second neutralization/oxidation reactor and additional filters could be constructed, as described in Appendix E.

4.3.3.6 Sludge Management

One of the four sludge management options described for Alternative 2 would be used. Alternative 3 is expected to produce about 10 percent less sludge than Alternative 2 as a result of the mine flow reductions caused by the mitigations, as discussed below for performance objectives.

4.3.3.7 Performance Monitoring and Phased Approach

Performance monitoring will be analyzed to assess the remedy performance, and also to determine if additional mitigations and/or treatment capacity are warranted using the phased approach. This would be done using performance objectives, performance monitoring, and performance evaluations.

Performance Objectives

The Alternative 3 mitigations are expected to reduce both peak and base flows, and also to reduce the amounts of treatment lime consumed and sludge generated. For this alternative, the treatment plant is initially sized at 2,500 gpm for optimum treatment and filtration performance as described above. Thus the mitigations, in conjunction with in-mine storage, are expected to reduce the peak flows to less than 2,500 gpm at the Kellogg Tunnel portal. Based on the range of percent flow volume reductions (see Table 4-3) and the given uncertainties associated with these estimates, a 10 percent reduction in annual AMD volume, lime consumption, and sludge production is estimated for Alternative 3.

The following summarizes the Alternative 3 mitigation performance objectives:

- Peak Kellogg Tunnel Flow: 2,500 gpm (after in-mine storage)
- Annual AMD Volume Reduction: 10 percent
- Annual Lime Reduction: 10 percent

- Annual Sludge Reduction: 10 percent

Performance Monitoring

Baseline data collected prior to installation of mitigations will provide the basis for determining if the installed mitigations have performed as expected and met the performance objectives. Subsequent performance monitoring data will be contrasted against the baseline data.

The performance monitoring period is expected to be up to 10 years, depending on the hydrologic conditions that affect the flow in West Fork Milo Creek and mine recharge (such as total rainfall and intensity, snow depth and melt rate, and temperature). For example, a relatively dry year with gradual spring warming may not result in significant flow in the West Fork Milo Creek diversion system. Hence, the ability of the West Fork Milo Creek Diversion to reduce peak Kellogg Tunnel flows to less than 2,500 gpm could not be assessed.

The specific monitoring program would be fully defined during remedial design. The following are the anticipated monitoring requirements, which include both surface and in-mine locations. Data collection is expected to be continuous at all sites except where noted below.

- Flow rate in West Fork Milo Creek at the diversion structure and one or two locations upgradient
- The quantity of water diverted by the West Fork Milo Creek Diversion
- The quantity of water diverted by the Phil Sheridan diversion system
- The quantity of water diverted by the existing Mainstem Milo Creek Diversion
- The water depths in all the Milo Gulch piezometers
- Periodic meteorological data consisting of precipitation, snowpack depth and water content, and temperature
- Mine water monitoring at the Kellogg Tunnel portal and at the locations used in the 1998/1999 program. This would include periodic measurement of flow and AMD chemistry, and could include continuous recording at some sites.
- CTP monitoring as required for demonstration of meeting discharge levels. This is expected to include flow measurements, daily samples for pH, TSS, and total metals, and process control monitoring.

Performance Evaluation and Decision Process

Additional mitigations to be considered for implementation are those described in this RI/FS, and also any additional ones identified during performance monitoring. The decision to add additional mitigations or treatment plant capacity will be based on performance evaluations and cost/benefit analyses as described below:

- Performance Evaluations - Periodic reviews, such as once per year, would be conducted by a technical review group to assess the performance of the mitigations with respect to the performance objectives. This would include refinement of the site conceptual model, reassessment of the estimated effectiveness for the remaining mitigations not yet implemented, and recommendations for changes to the monitoring program.

NEXT

- Cost / Benefit Analysis – A cost / benefit analysis would be conducted if the performance evaluations suggest additional mitigations should be considered. This would consist of updating the mitigation cost estimates, and also the estimates of mitigation benefits. Cost factors to be considered are capital, annual, and life-cycle costs. Benefits to be considered are capital savings if additional treatment plant expansion can be avoided; cost savings for AMD collection, conveyance, storage, treatment, and sludge reductions; and enhanced remedy protectiveness if the flow rate or strength of the AMD can be reduced, thereby reducing the potential for an uncontrolled release to Bunker Creek.
- Selection – Additional mitigations implemented would be those that have favorable cost / benefit ratios, and / or provide required additional protectiveness.

4.3.3.8 Alternative 3 Summary

Table 4-7 summarizes the components of Alternative 3, the Phased Mitigations / Treatment alternative.

4.3.4 Alternative 4—Phased Mitigations/Treatment with Plugging of Near-Stream Workings

Alternative 4 is similar to Alternative 3 except it would include initially plugging the Small Hopes Drift below Mainstem Milo Creek and the Inez Shaft below Deadwood Creek. This would reduce or eliminate the possibility of high stream flows eroding direct flow paths into the mine through these areas.

Table 4-8 summarizes the components of Alternative 4.

4.3.5 Alternative 5—Treatment with All Mitigations

Alternative 5 does not use a phased approach. It consists of initial implementation of all the mitigations listed in Table 3-3 and construction of 2,500 gpm of upgraded treatment plant capacity. Mitigation performance monitoring is assumed to be conducted for only 5 years, because no future mitigations would be implemented. Table 4-9 summarizes the components of Alternative 5.

TABLE 4-1
Estimated Range of Kellogg Tunnel Flow Reductions Resulting from Mitigations
Bunker Hill Mine Water RI/FS Report

Model KT Flow Range	Estimated KT Flow Reductions[1]
KT < 1,500 gpm (low and base flow conditions)	0 percent to 30 percent
1,500 gpm < KT < 2,500 gpm (medium to medium-high flow conditions)	15 percent to 50 percent
2,500 gpm < KT < 3,500 gpm (medium-high to high flow conditions)	30 percent to 70 percent
KT > 3,500 gpm (high to very high flow conditions)	60 percent to 90 percent

[1]The percent flow reductions are for only the increment of flow in the flow interval. For example, if the KT flow were 5,000 gpm and the percent flow reductions for the ranges were 20 percent, 40 percent, 60 percent, and 90 percent, the corresponding flow reductions would be 300, 400, 600, and 1,350 gpm, and the total KT flow would be reduced by 2,650 gpm.

KT = Kellogg Tunnel

TABLE 4-2
Maximum Allowable CTP Effluent Flow Rates to Meet the TMDL Discharge Conditions
Bunker Hill Mine Water RI/FS Report

	Cadmium	Lead	Zinc
7Q10 River Flow Condition			
TMDL (lb/day)	0.0233	0.135	2.43
Max CTP Flow (gpm)	2,773	11,245	2,892
10 percent River Flow Condition			
TMDL (lb/day)	0.031	0.178	3.22
Max CTP Flow (gpm)	3,689	14,827	3,832
50 percent River Flow Condition			
TMDL (lb/day)	0.0659	0.334	6.60
Max CTP Flow (gpm)	7,842	27,821	7,854
90 percent River Flow Condition			
TMDL (lb/day)	0.103	0.297	8.90
Max CTP Flow (gpm)	12,257	24,739	10,591

Note: Anticipated CTP Effluent Concentrations:
Cadmium = <0.70 µg/L
Lead = <1.0 µg/L
Zinc = <70 µg/L
TMDL = total maximum daily load
CTP = Central Treatment Plant

TABLE 4-3
Estimated KT Peak, Average, and Average Annual Volume Reductions[1]
Bunker Hill Mine Water RI/FS Report

	Modeled Range of Mitigation Effectiveness: KT < 1,500 gpm; 1,500<KT<2,500; 2,500<KT<3,500; 3,500 < KT					
	(0,0,0,0%)	**(5,15,30,60%)**	**(10,25,40,70%)**	**(15,30,50,80%)**	**(20,35,60,90%)**	**(30,50,70,90%)**
Peak KT Flow (gpm)	6,700[2]	4,270[2]	3,660[2]	3,120[2]	2,570[2]	2,170[2]
Avg. Annual KT Flow (gpm)	1,700	1,570	1,470	1,380	1,290	1,110
Percent Estimated Average Annual Flow Volume Reduction	0 percent	7.6 percent	13.5 percent	18.8 percent	24.1 percent	34.7 percent

[1]The values are calculated using the 1973, 1974, 1981, 1982, and 1996 water years.
[2]Assumes no in-mine storage
KT = Kellogg Tunnel

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TABLE 4-4
Alternatives Summary
Bunker Hill Mine Water RI/FS Report

AMD Mitigations	AMD Collection	AMD Storage	AMD Conveyance	AMD Treatment	Sludge Management	Performance Monitoring
Alternative 1—No Further Action						
None	Existing System	Lined pond for routine storage. In-mine for contingency storage using the existing diversions, pumping systems, and equipment.	The existing pipeline to the lined pond.	Existing CTP with no upgrades for TMDL achievement or repair of equipment failure. The CTP will be shut down when the existing sludge disposal bed is full.	Existing unlined disposal bed on CIA that has about 3 to 5 years remaining capacity. No additional disposal capacity will be built.	Existing monitoring, KT portal (flow and chemistry) and CTP (flow and chemistry).
Alternative 2—Treatment Only						
None	Same as Alternative 1	Same as Alternative 1	The existing pipeline to the lined pond and new section for direct feed to the CTP.	5,000 gpm—updated and configured for more reliable operation and meeting the new discharge levels.	One of three onsite disposal options or one offsite option.	Same as Alternative 1
Alternative 3—Phased Treatment/Mitigations						
Initially: West Fork Milo Creek Diversion, rehabilitate Phil Sheridan Diversion, plug drill holes. Phased Implementation: Other mitigations as determined by performance monitoring and evaluation.	Same as Alternative 1	Lined pond for routine storage. In-mine for contingency storage. This includes a new gravity diversion system down No. 2 Shaft for east side water and one down a location in the Barney Drift for west side water, and an upgraded pumping system using two vertical turbine pumps.	Same as Alternative 2	Initially: 2,500 gpm— updated and configured for more reliable operation and meeting the new discharge levels. Phased Implementation: Additional capacity as determined by performance monitoring and evaluation.	Same as Alternative 2	Up to 10 Years for Phased Approach: Surface streams (flow), Piezometers (groundwater depth) In-mine (flow and chemistry), Ongoing: KT portal (flow and chemistry), and CTP (flow and chemistry).
Alternative 4—Phased Treatment/Mitigations with Plugging of Near-Stream Workings						
Initially: Same as Alternative 3 plus plug the Inez Shaft, and plug the Small Hopes drift. Phased Implementation: Other mitigations as determined by monitoring and evaluation.	Same as Alternative 1	Same as Alternative 3	Same as Alternative 2	Same as Alternative 3	Same as Alternative 2	Same as Alternative 3
Alternative 5—Treatment with All Mitigations						
Same as Alternative 4 plus upgrade Phil Sheridan diversion system to capture more subsurface flow, South Fork Milo Creek Diversion, improve the existing Milo Creek diversion, sidehill diversions in West Milo Creek basin, bypass Bunker Hill Dam. No phased implementation of subsequent mitigations.	Same as Alternative 1	Same as Alternative 3	Same as Alternative 2	2,500 gpm— updated and configured for more reliable operation and meeting the new discharge levels. No phased implementation of additional capacity.	Same as Alternative 2	Up to 5 Years for Mitigation Assessment: Surface streams (flow), Piezometers (groundwater depth), In-mine (flow and chemistry), Ongoing: KT portal (flow and chemistry), and CTP (flow and chemistry).

KT – Kellogg Tunnel
CTP – Central Treatment Plant

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TABLE 4-5
Summary of Alternative 1—No Further Action
Bunker Hill Mine Water RI/FS Report

Remedial Component	Description
AMD Mitigations	None—No mitigations would be implemented to reduce water infiltration to the mine and the volume of mine water requiring management.
AMD Collection	The AMD would be collected as is currently done, using the ditches in the drifts and the existing mine pool pumping system, until the CTP is shut down in 3 to 5 years. At this time, all in-mine AMD collection would cease unless done unilaterally by the mine owner for mining operations.
AMD Conveyance	The existing concrete channel and Parshall flume at the KT portal would continue to collect the flow from the KT ditch, measure the flow, and channel it into the buried pipeline for transport to the lined pond. This would continue until the CTP is shut down, at which time the system would not be maintained. The AMD will flow untreated into Bunker Creek.
AMD Storage	The existing in-mine storage system would continue to be used for 3 to 5 years until the CTP is shut down, at which time there would be no need for AMD storage.
AMD Treatment	The existing lime neutralization treatment plant (CTP) would be used with no upgrades for TMDL achievement. No major repairs or improvements would be made, leading to more frequent and longer-duration shutdowns, possibly causing complete CTP failure prior to the sludge impoundment becoming full. Once the sludge impoundment is full (3 to 5 years), the plant would be shut down permanently. The AMD would flow untreated into Bunker Creek.
Sludge Management	Sludge would continue to be pumped from the sludge thickener into the unlined sludge disposal bed on the CIA until it is full. No replacement storage would be provided. Once the existing storage is full, the CTP would need to be shut down because it cannot operate without sludge disposal.
Performance Monitoring	Existing monitoring would be continued until the CTP is shut down, at which time all monitoring would cease.

AMD = acid mine drainage
CIA = Central Impoundment Area
CTP = Central Treatment Plant
KT = Kellogg Tunnel
TMDL = total maximum daily load

TABLE 4-6
Summary of Alternative 2—Treatment Only
Bunker Hill Mine Water RI/FS Report

Remedial Component	Description
AMD Mitigations	None—No mitigations would be implemented to reduce water infiltration to the mine and the volume of mine water requiring management.
AMD Collection	The gravity drainage AMD would be collected as is currently done using the ditches in the drifts. The mine pool would continue to be pumped.
AMD Conveyance	The existing concrete channel and Parshall flume at the KT portal would continue to collect the flow from the KT ditch, measure the flow, and channel it into the buried pipeline. A new section of pipe would normally convey the AMD directly to the CTP, bypassing the lined pond to reduce sediment accumulation.
AMD Storage	The existing 7-million-gallon lined pond would continue to be used for routine storage. The existing in-mine storage system from about 30 feet below 11 Level and up would be used for contingency storage. The existing diversion system to pump from the gravity ditches into the mine pool would be used, and the existing mine pool extraction system would be used to remove water from storage.
AMD Treatment	The CTP would be upgraded to a 5,000 gpm capacity using the high-density sludge lime neutralization process with tri-media filters for achievement of the new treatment discharge levels.
Sludge Management	One of the four sludge management options would be used:
	Option A: Disposal of raw sludge in onsite sludge disposal beds located on the CIA that both dewater and permanently store the sludge
	Option B: Mechanical sludge dewatering and disposal of dry sludge in an offsite landfill
	Option C: Disposal of raw sludge in onsite sludge disposal beds located above the smelter closure area
	Option D: Sludge drying using sludge drying beds on the CIA and annual excavation and disposal of dry sludge in an onsite landfill located above the smelter closure area
Performance Monitoring	Monitoring would be conducted at the KT portal and at the CTP effluent flow to Bunker Creek, as is currently done. The KT portal monitoring is expected to include continuous flow recording and periodic (weekly or bi-weekly) samples for pH, TSS, lime demand/solids formed, and total cadmium, lead, and zinc analysis. The CTP effluent flow would be monitored and is expected to consist of daily sampling for pH, TSS, and total metals.

AMD = acid mine drainage
CIA = Central Impoundment Area
CTP = Central Treatment Plant
KT = Kellogg Tunnel
TMDL = total maximum daily load
TSS = total suspended solids

TABLE 4-7
Summary of Alternative 3—Phased Mitigations/Treatment
Bunker Hill Mine Water RI/FS Report

Remedial Component	Description
AMD Mitigations	Initial mitigations would be as follows. Additional mitigations would be phased: • West Fork Milo Creek Diversion • Rehabilitate the Phil Sheridan Diversion • Drill hole plugging
AMD Collection	The gravity drainage AMD would be collected as is currently done using the ditches in the drifts. The mine pool would continue to be pumped.
AMD Conveyance	The existing concrete channel and Parshall flume at the KT portal would continue to collect the flow from the KT ditch, measure the flow, and channel it into the buried pipeline. A new section of pipe would normally convey the AMD directly to the CTP, bypassing the lined pond.
AMD Storage	The existing 7-million-gallon lined pond would continue to be used for routine storage. In-mine storage from about 30 feet below 11 Level and up would be used for contingency storage. Gravity diversions to the mine pool would be constructed, and two 700-gpm pumps installed in No. 2 Shaft to remove stored water and for ongoing mine pool pumping.
AMD Treatment	The initial optimum treatment and filtration capacity would be 2,500 gpm, but the lime feed and hydraulic throughput capacity would be 5,000 gpm as a contingency measure for higher-than-expected KT flows. A second neutralization/oxidation reactor and additional filters would be constructed later if needed. Alternative 3 is expected to use about 10 percent less lime than Alternatives 1 or 2.
Sludge Management	Alternative 3 is expected to produce about 10 percent less sludge than Alternatives 1 or 2. One of the following four sludge management options would be used: Option A: Disposal of raw sludge in onsite sludge disposal beds located on the CIA that both dewater and permanently store the sludge Option B: Mechanical sludge dewatering and disposal of dry sludge in an offsite landfill Option C: Disposal of raw sludge in onsite sludge disposal beds located above the smelter closure area Option D: Sludge drying using sludge drying beds on the CIA and annual excavation and disposal of dry sludge in an onsite landfill located above the smelter closure area
Performance Monitoring	Performance monitoring and evaluation for up to 10 years would be used to support the phased approach, and would consist of: • The quantity of water diverted by the West Fork Milo Creek Diversion, the Phil Sheridan Diversion, and the existing Mainstem Milo Creek Diversion • The water depths in all the Milo Gulch piezometers • Meteorological data consisting of precipitation, snowpack depth and water content, and temperature • KT portal monitoring and in-mine monitoring at the locations used in the 1998/1999 program for flow and chemistry (KT portal monitoring would continue beyond 10 years) • CTP discharge monitoring. This is expected to include flow measurements, daily samples for pH, TSS, and total metals, and process control monitoring (would continue beyond 10 years).

AMD = acid mine drainage
CIA = Central Impoundment Area
CTP = Central Treatment Plant
KT = Kellogg Tunnel
TSS = total suspended solids

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TABLE 4-8
Summary of Alternative 4—Phased Mitigations/Treatment with Plugging of Near-Stream Workings
Bunker Hill Mine Water RI/FS Report

Remedial Component	Description
AMD Mitigations	Initial mitigations would be as follows. Additional mitigations would be phased: • West Fork Milo Creek Diversion • Rehabilitate the Phil Sheridan Diversion • Drill hole plugging • Plug the Small Hopes drift below Mainstem Milo Creek • Plug the Inez Shaft below Deadwood Creek
AMD Collection	The gravity drainage AMD would be collected as is currently done using the ditches in the drifts. The mine pool would continue to be pumped.
AMD Conveyance	The existing concrete channel and Parshall flume at the KT portal would continue to collect the flow from the KT ditch, measure the flow, and channel it into the buried pipeline. A new section of pipe would normally convey the AMD directly to the CTP, bypassing the lined pond.
AMD Storage	The existing 7-million-gallon lined pond would continue to be used for routine storage. In-mine storage from about 30 feet below 11 Level and up would be used for contingency storage. Gravity diversions to the mine pool would be constructed, and two 700-gpm pumps installed in No. 2 Shaft to remove stored water and for ongoing mine pool pumping.
AMD Treatment	The initial optimum treatment and filtration capacity would be 2,500 gpm, but the lime feed and hydraulic throughput capacity would be 5,000 gpm as a contingency measure for higher-than-expected KT flows. A second neutralization/oxidation reactor and additional filters would be constructed later if needed. Alternative 4 is expected to use about 10 percent less lime than Alternatives 1 or 2.
Sludge Management	Alternative 4 is expected to produce about 10 percent less sludge than Alternatives 1 or 2. One of the following four sludge management options would be used: Option A: Disposal of raw sludge in onsite sludge disposal beds located on the CIA that both dewater and permanently store the sludge Option B: Mechanical sludge dewatering and disposal of dry sludge in an offsite landfill Option C: Disposal of raw sludge in onsite sludge disposal beds located above the smelter closure area Option D: Sludge drying using sludge drying beds on the CIA and annual excavation and disposal of dry sludge in an onsite landfill located above the smelter closure area
Performance Monitoring	Performance monitoring and evaluation for up to 10 years would be used to support the phased approach, and would consist of: • The quantity of water diverted by the West Fork Milo Creek Diversion, the Phil Sheridan Diversion, and the existing Mainstem Milo Creek Diversion • The water depths in all the Milo Gulch piezometers • Meteorological data consisting of precipitation, snowpack depth and water content, and temperature • KT portal monitoring and in-mine monitoring at the locations used in the 1998/1999 program for flow and chemistry (KT portal monitoring would continue beyond 10 years) • CTP discharge monitoring. This is expected to include flow measurements, daily samples for pH, TSS, and total metals, and process control monitoring (would continue beyond 10 years).

AMD = acid mine drainage
CIA = Central Impoundment Area
CTP = Central Treatment Plant
KT = Kellogg Tunnel
TSS = total suspended solids

TABLE 4-9
Summary of Alternative 5—Treatment with All Mitigations
Bunker Hill Mine Water RI/FS Report

Remedial Component	Description
AMD Mitigations	The following mitigations would be constructed. A phased approach would not be used. • West Fork Milo Creek Diversion • Rehabilitate the Phil Sheridan Diversion • Drill hole plugging • Plug the Small Hopes Drift below Mainstem Milo Creek • Plug the Inez Shaft below Deadwood Creek • Sidehill diversion in West Fork Milo Basin • South Fork Milo Creek Diversion • Bypass Bunker Hill Dam in Mainstem Milo Creek • Improve existing diversion in Mainstem Milo Creek • Upgrade Phil Sheridan raise system in West Fork Milo Basin
AMD Collection	The gravity drainage AMD would be collected as is currently done using the ditches in the drifts. The mine pool would continue to be pumped.
AMD Conveyance	The existing concrete channel and Parshall flume at the KT portal would continue to collect the flow from the KT ditch, measure the flow, and channel it into the buried pipeline. A new section of pipe would normally convey the AMD directly to the CTP, bypassing the lined pond.
AMD Storage	The existing 7-million-gallon lined pond would continue to be used for routine storage. In-mine storage from about 30 feet below 11 Level and up would be used for contingency storage. Gravity diversions to the mine pool would be constructed, and two 700-gpm pumps installed in No. 2 Shaft to remove stored water and for ongoing mine pool pumping.
AMD Treatment	The CTP would be upgraded for optimum treatment and filtration at 2,500 gpm capacity, but the lime feed and hydraulic throughput capacity would be 5,000 gpm as a contingency measure for higher-than-expected KT flows. A phased approach for considering future CTP capacity upgrades would not be used. Alternative 5 is expected to use about 20 percent less lime than Alternatives 1 or 2.
Sludge Management	Alternative 5 is expected to produce about 20 percent less sludge than Alternatives 1 or 2. One of the following four sludge management options would be used: Option A: Disposal of raw sludge in onsite sludge disposal beds located on the CIA that both dewater and permanently store the sludge Option B: Mechanical sludge dewatering and disposal of dry sludge in an offsite landfill Option C: Disposal of raw sludge in onsite sludge disposal beds located above the smelter closure area Option D: Sludge drying using sludge drying beds on the CIA and annual excavation and disposal of dry sludge in an onsite landfill located above the smelter closure area
Performance Monitoring	Mitigation performance monitoring would be conducted for up to 5 years, and would consist of: • The quantity of water diverted by the West Fork Milo Creek Diversion, South Fork Milo Creek Diversion, the Phil Sheridan Diversion, and the existing Mainstem Milo Creek Diversion • The water depths in all the Milo Gulch piezometers • Meteorological data consisting of precipitation, snowpack depth and water content, and temperature • KT portal monitoring and in-mine monitoring at the locations used in the 1998/1999 program for flow and chemistry (KT portal monitoring would continue beyond 10 years) • CTP discharge monitoring would be conducted, and would continue beyond 5 years. This is expected to include flow measurements, daily samples for pH, TSS, and total metals, and process control monitoring.

AMD = acid mine drainage
CIA = Central Impoundment Area
CTP = Central Treatment Plant
KT = Kellogg Tunnel
TSS = total suspended solids

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Notes:

→ Mine Water Flow Direction

1. Calculate TMDLs - TMDLs are calculated for cadmium, lead and zinc (lbs/day) according to daily SFCdA River flows. Discharge flows are then calculated by dividing the TMDL by effluent concentrations (ug/L) that were input to the model. The minimum flow is selected from the three metals and termed "allowable discharge flow" (gpm).
2. KT flow is compared to CTP capacity. If mitigations are used, the KT flow is reduced accordingly. AMD is pumped or diverted until KT flow equals CTP capacity. AMD cannot be pumped if storage is empty, so in some cases KT flow is less than CTP capacity.
3. CTP discharge flow (gpm) is compared to the allowable discharge flow (gpm) calculated in Step 1. If CTP discharge flow is greater than allowable discharge flow, AMD is diverted to the Mine Pool until they are equal.
4. Storage is calculated by adding the pump/diversion rates determined in Step 2 to the diversion rates in Step 3.
5. If treated storage is selected in the model input without the alternative water use option, water that is diverted in the third step is first placed in a treated storage pond until it is full. Treated storage is placed in the SFCdA River when flows and therefore allowable discharge is greater than CTP discharge.
6. If alternative water use is selected as an option, alternative water use takes precedence over discharge to the SFCdA River or storage in the treated storage pond. In the event that the alternative water use demand is higher than the amount of water treated at the CTP, any water stored in the treated storage pond (if selected in the model input) will be used to meet the alternative water demand.

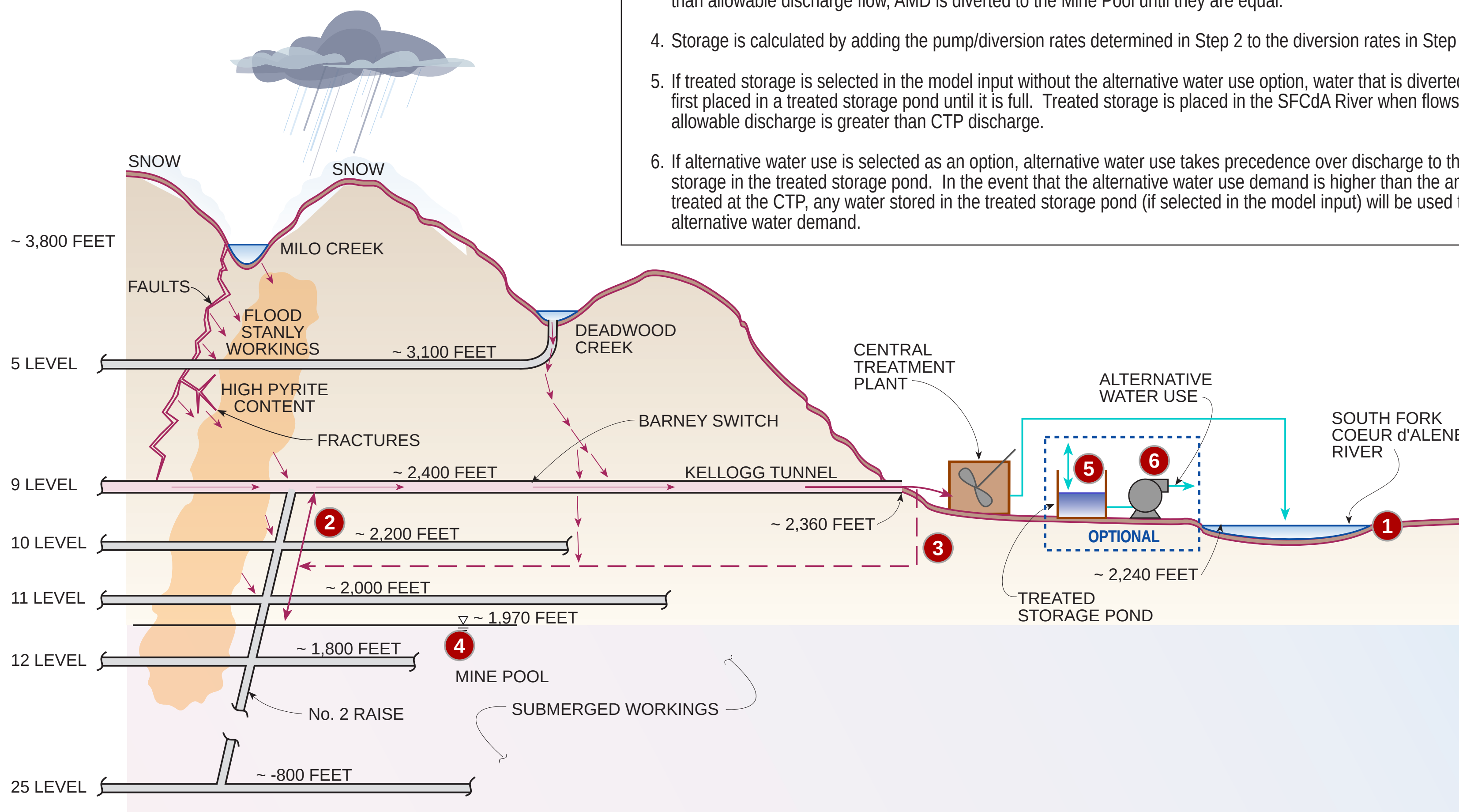

FIGURE 4-1

TMDL COMPUTER MODEL LOGIC

BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL

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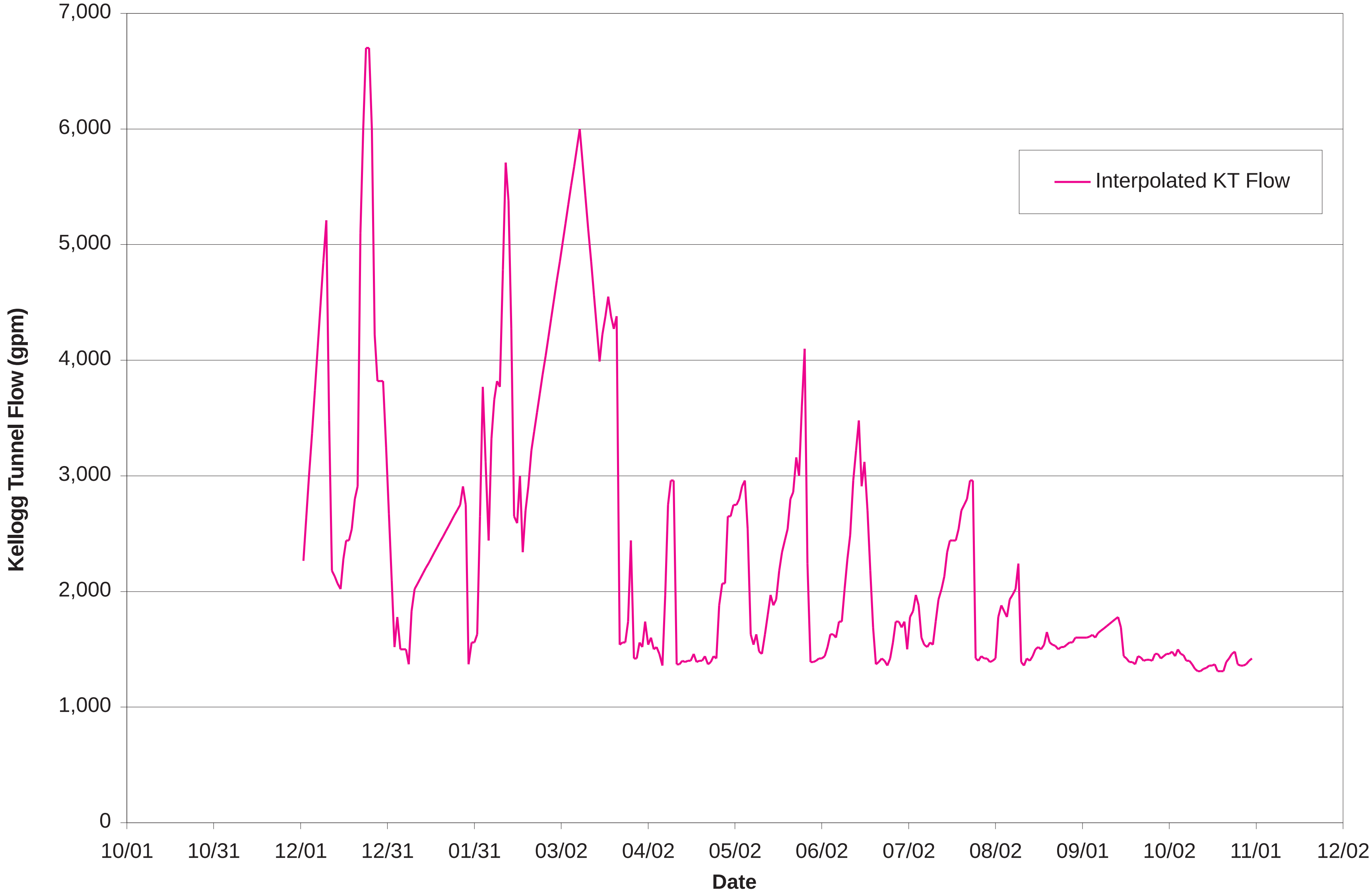

FIGURE 4-2
WATER YEAR 1973
KELLOGG TUNNEL HYDROGRAPH
BUNKER HILL MINE WATER MANAGEMENT RI/FS

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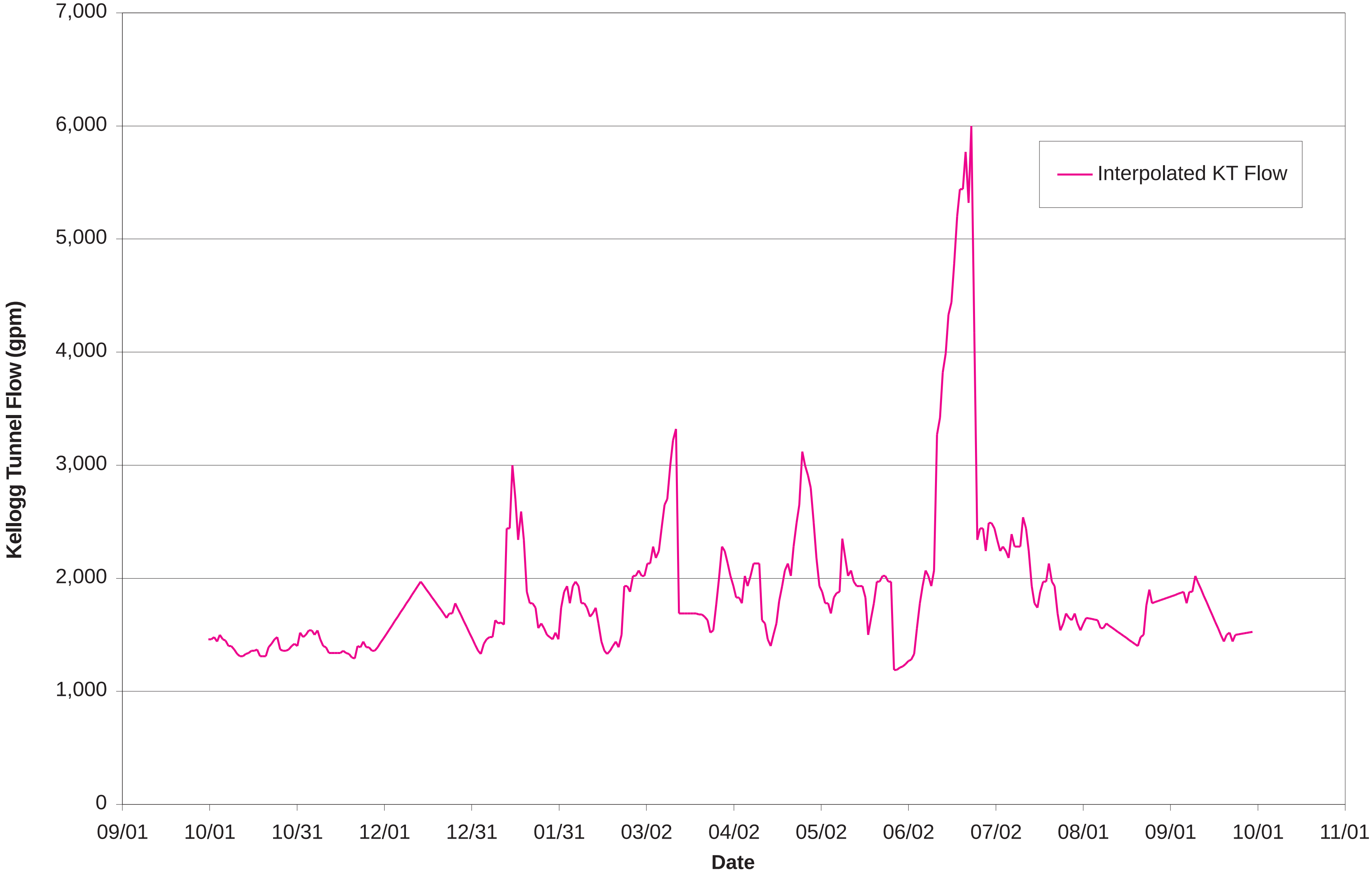

FIGURE 4-3
WATER YEAR 1974
KELLOGG TUNNEL HYDROGRAPH
BUNKER HILL MINE WATER MANAGEMENT RI/FS

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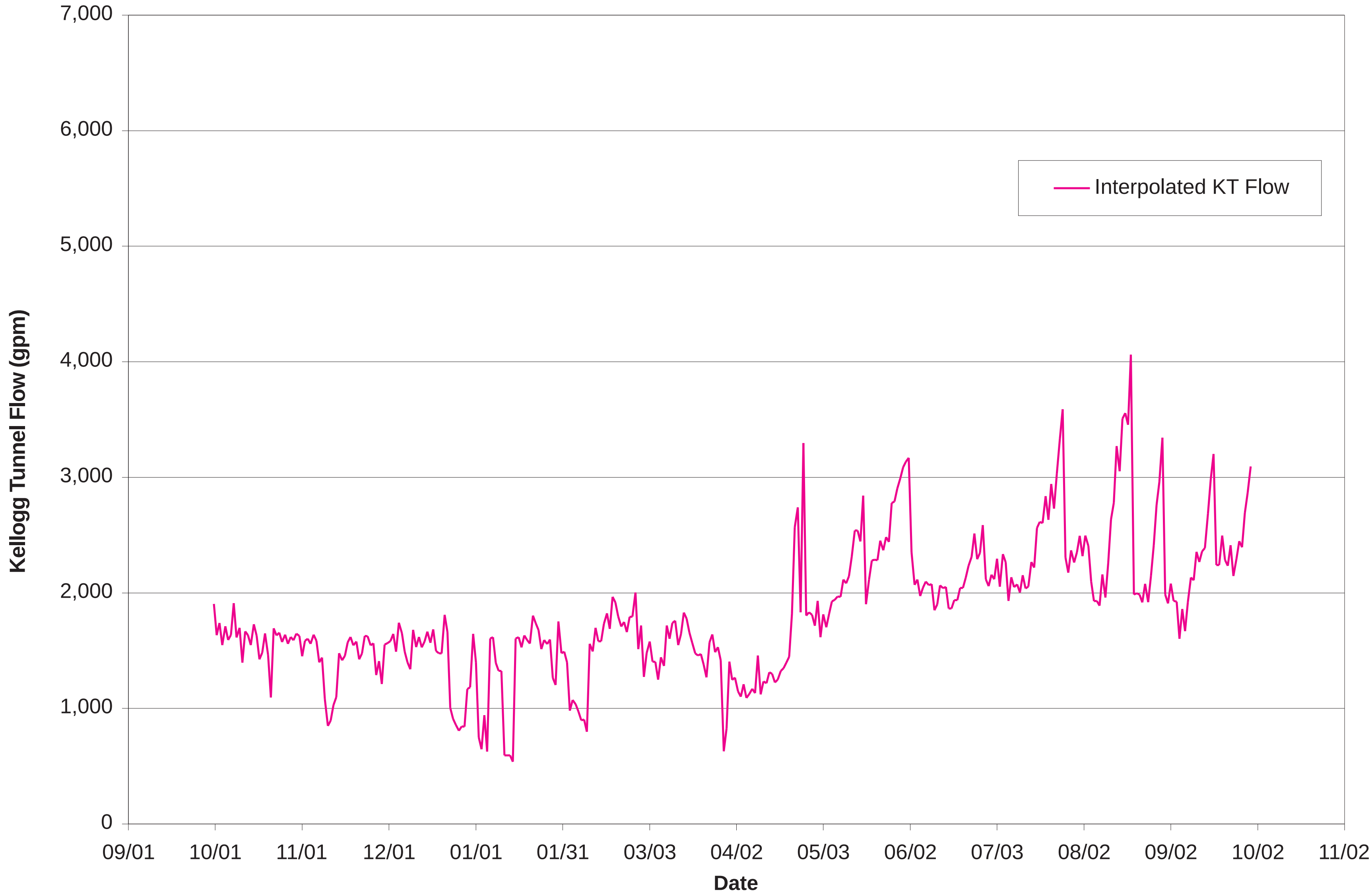

FIGURE 4-4
WATER YEAR 1981
KELLOGG TUNNEL HYDROGRAPH
BUNKER HILL MINE WATER MANAGEMENT RI/FS

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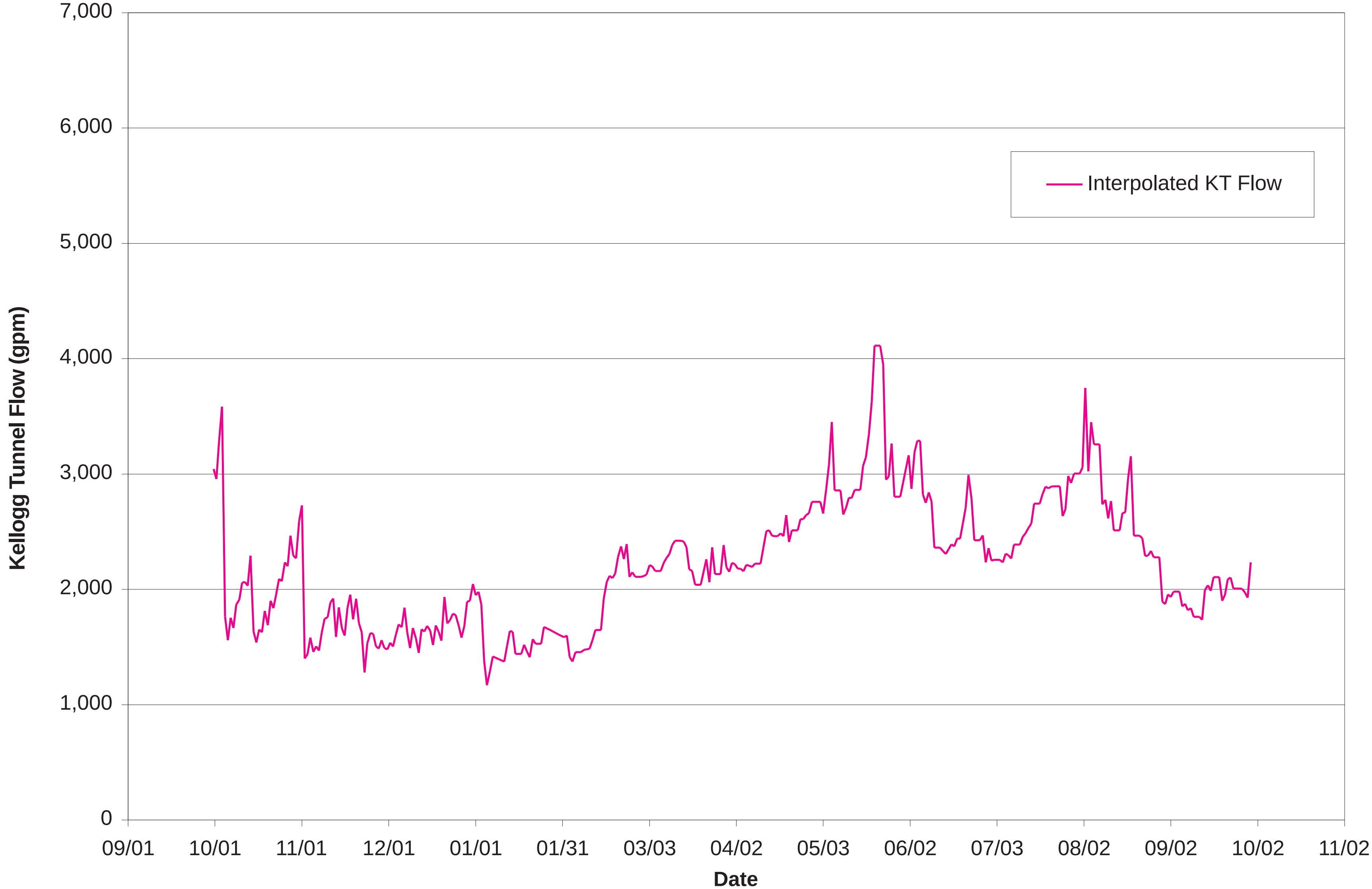

FIGURE 4-5
WATER YEAR 1982
KELLOGG TUNNEL HYDROGRAPH
BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL

NEXT

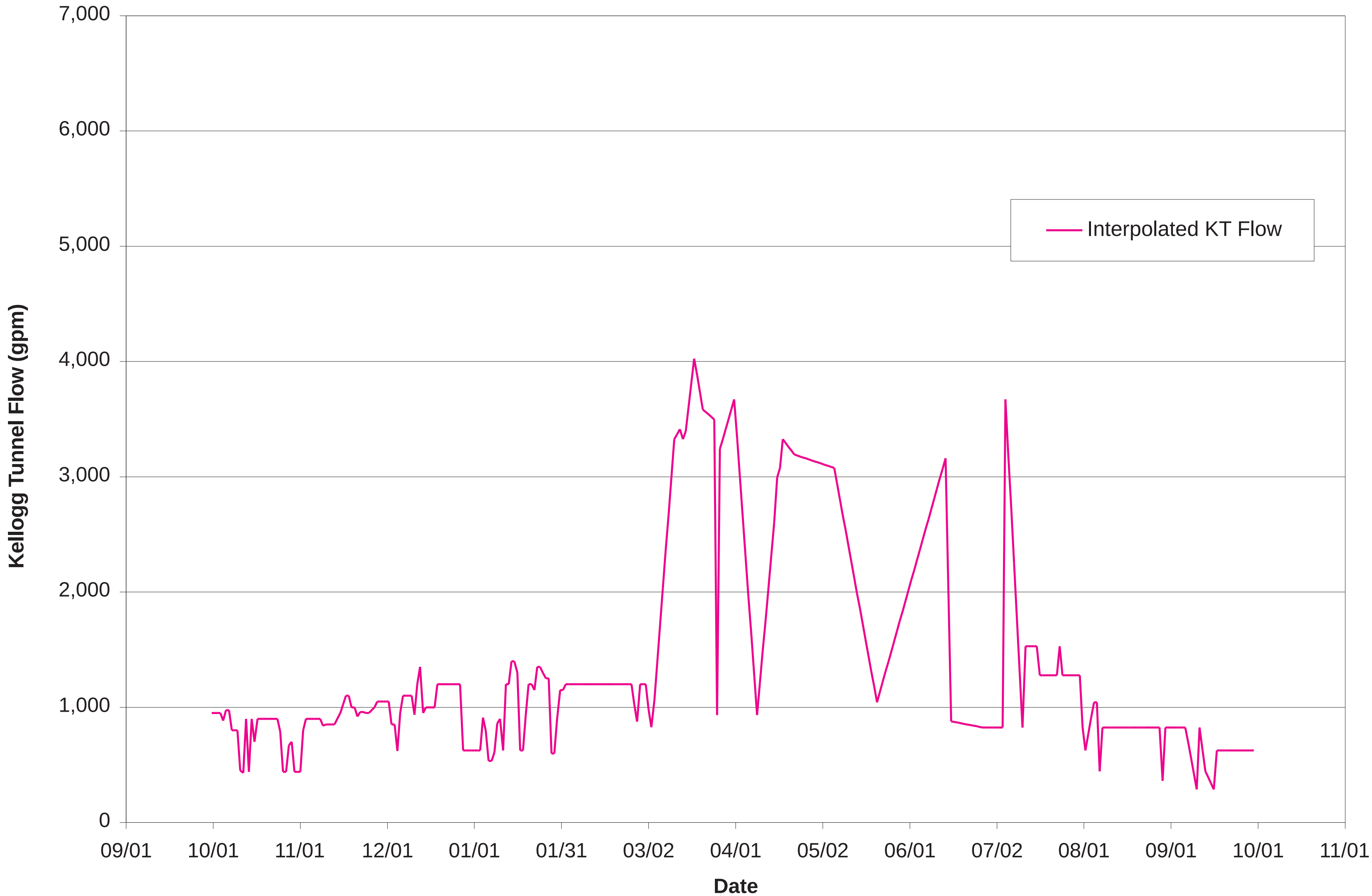

FIGURE 4-6
WATER YEAR 1996
KELLOGG TUNNEL HYDROGRAPH
BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL

NEXT

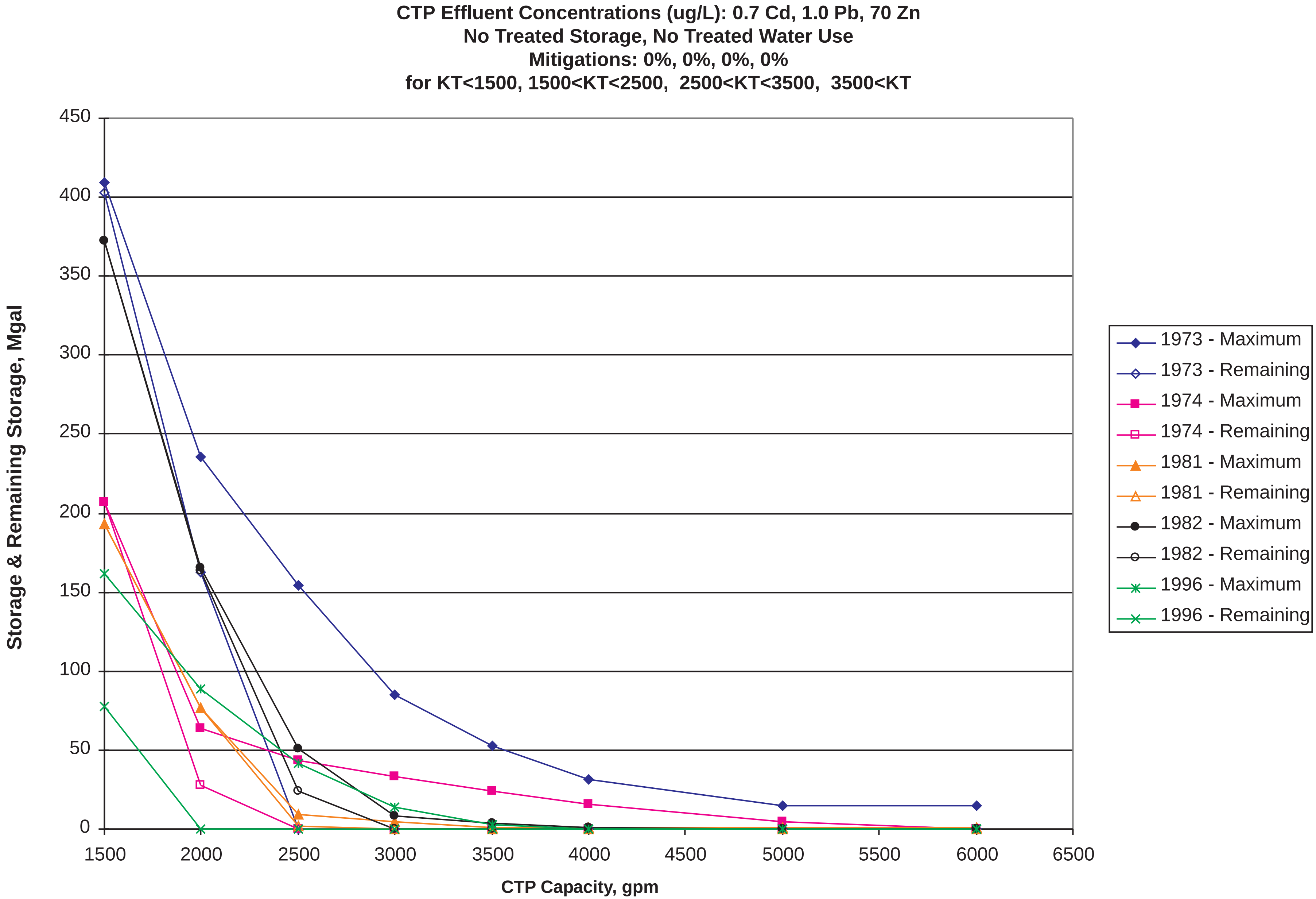

FIGURE 4-7

REQUIRED AND REMAINING STORAGE VS. CTP CAPACITY (0%, 0%, 0%, 0% EFFECTIVE MITIGATIONS)

BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL

NEXT

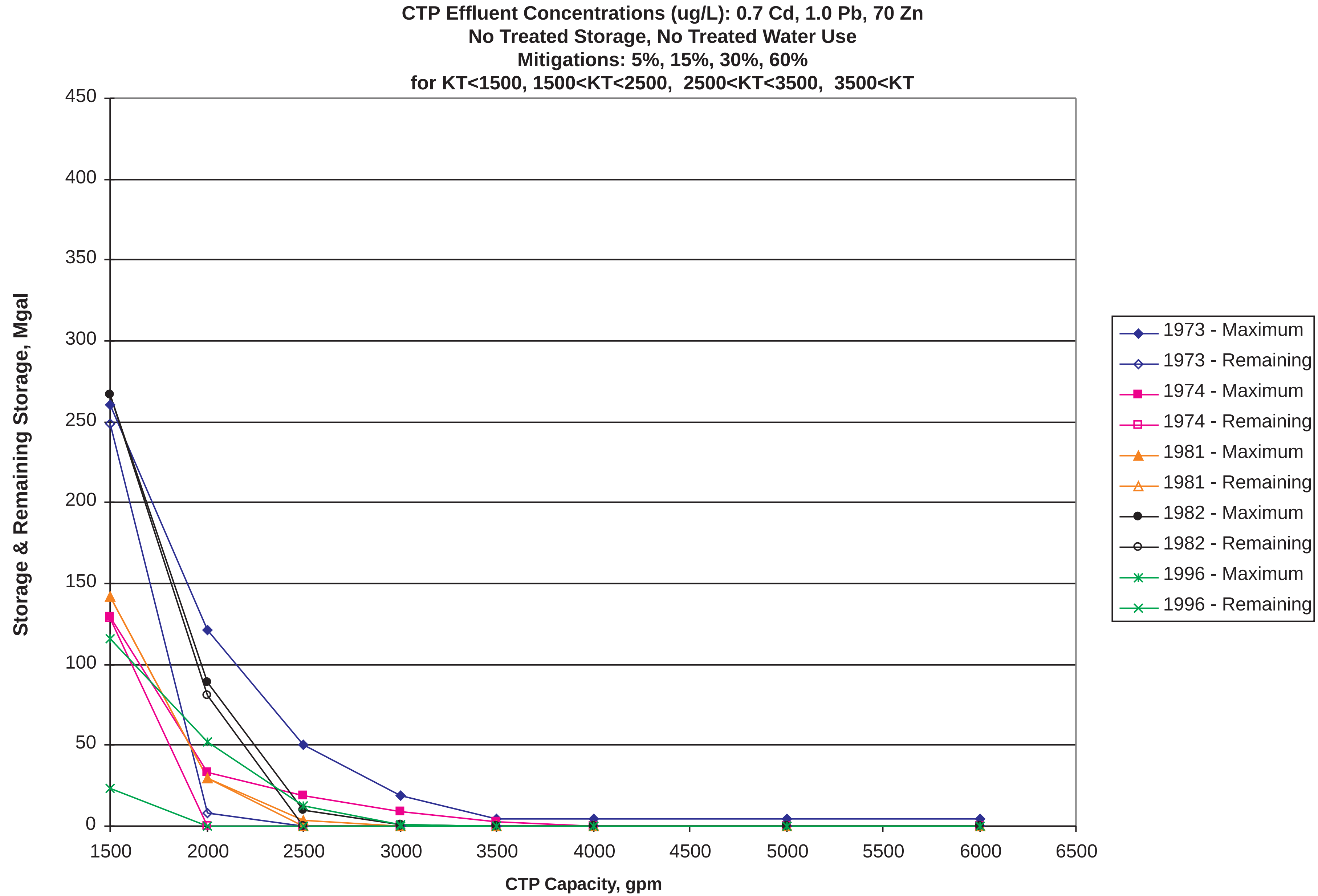

FIGURE 4-8

REQUIRED AND REMAINING STORAGE VS. CTP CAPACITY (5%, 15%, 30%, 60% EFFECTIVE MITIGATIONS)

BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL

NEXT

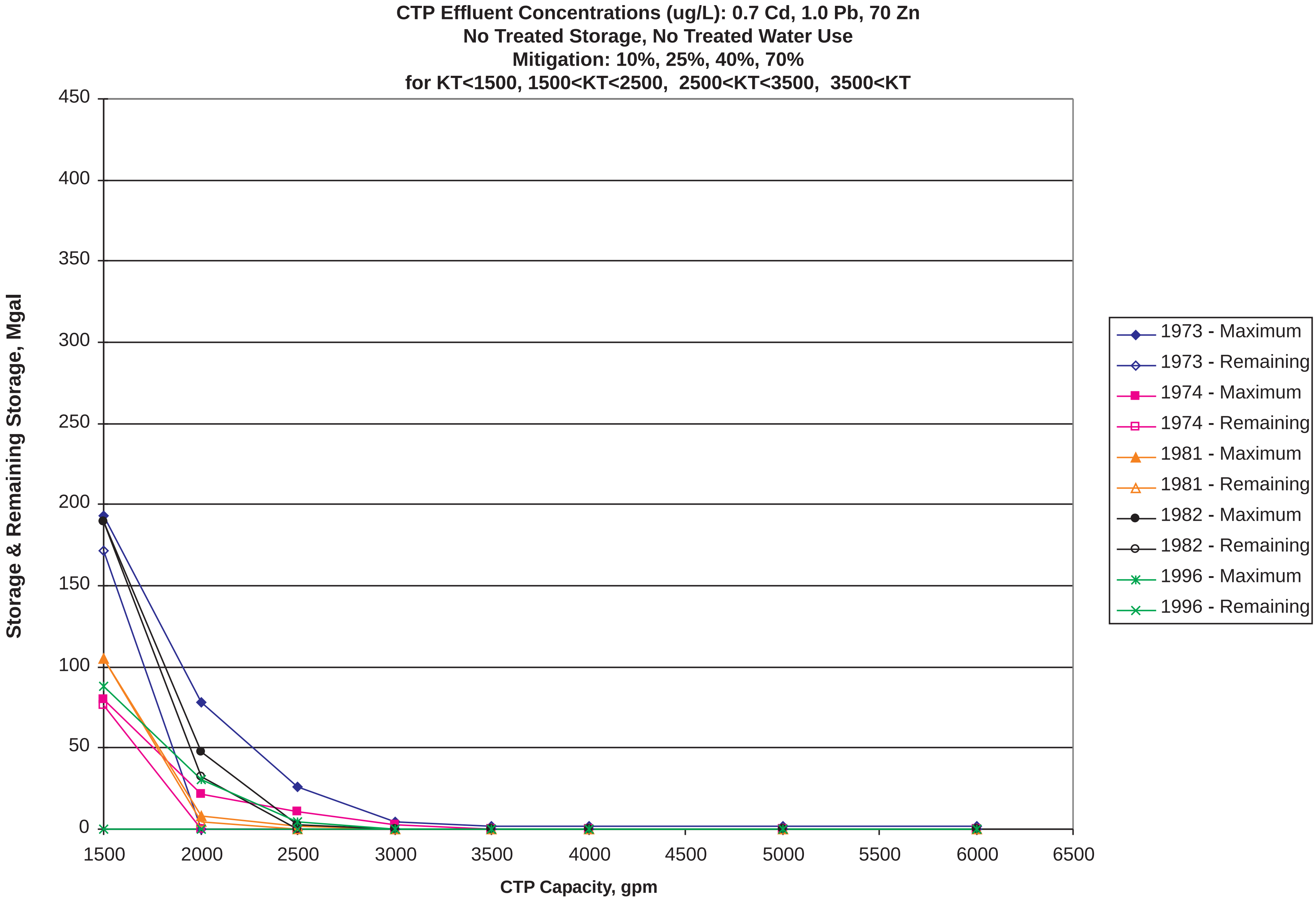

FIGURE 4-9

REQUIRED AND REMAINING STORAGE VS. CTP CAPACITY (10%, 25%, 40%, 70% EFFECTIVE MITIGATIONS)

BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL

NEXT

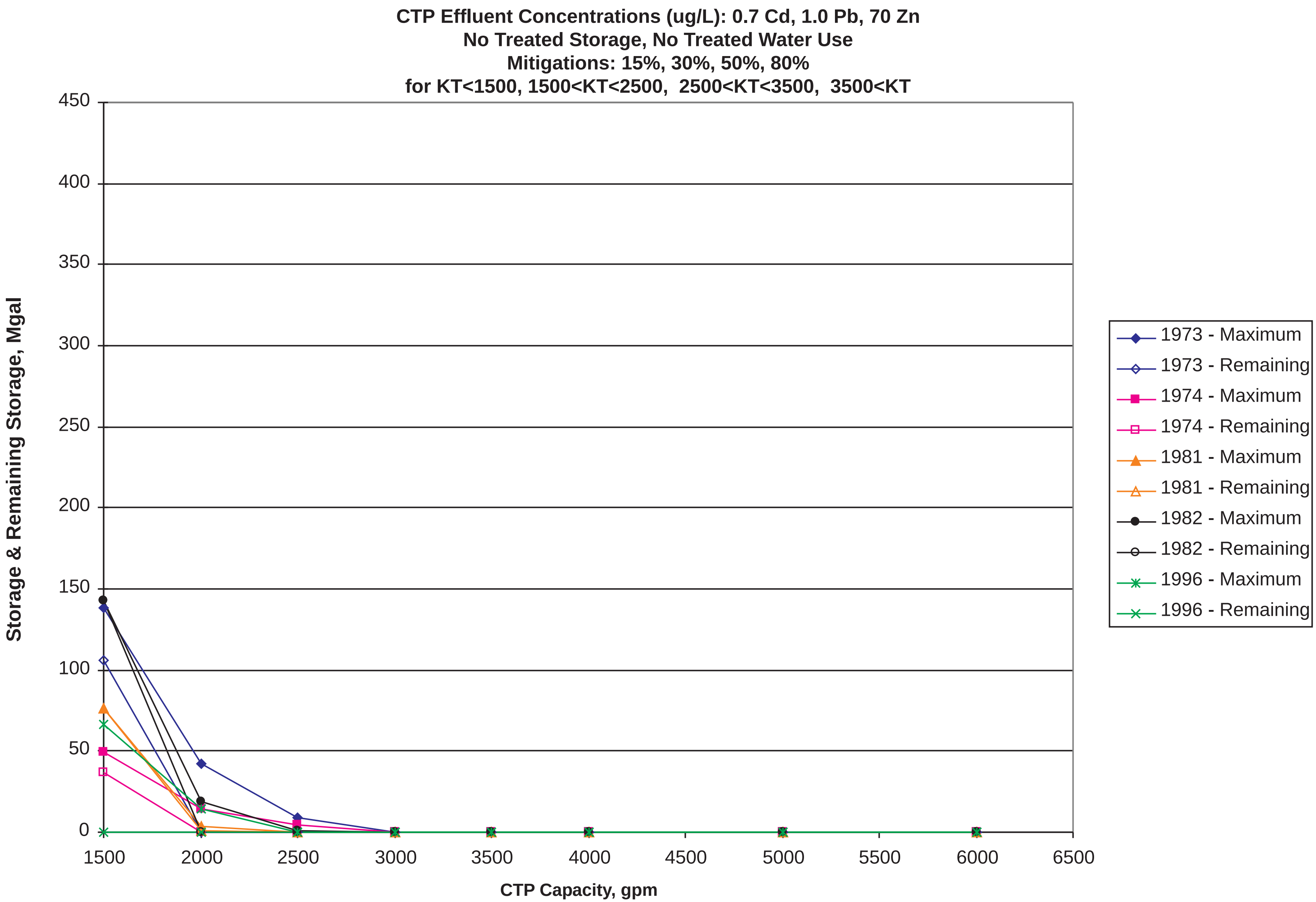

FIGURE 4-10

REQUIRED AND REMAINING STORAGE VS. CTP CAPACITY (15%, 30%, 50%, 80% EFFECTIVE MITIGATIONS)

BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL

NEXT

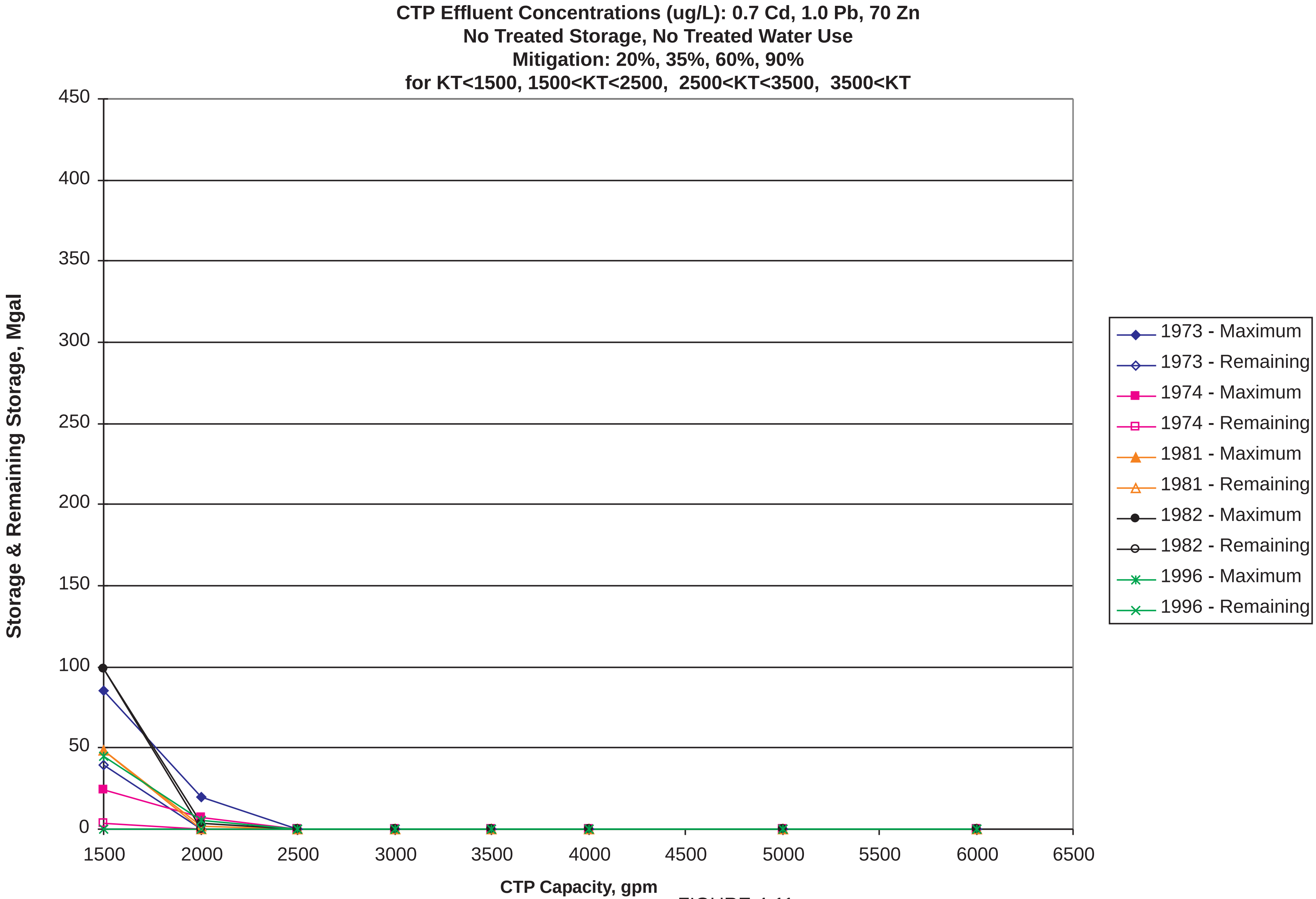

FIGURE 4-11

REQUIRED AND REMAINING STORAGE VS. CTP CAPACITY (20%, 35%, 60%, 90% EFFECTIVE MITIGATIONS)

BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL

NEXT

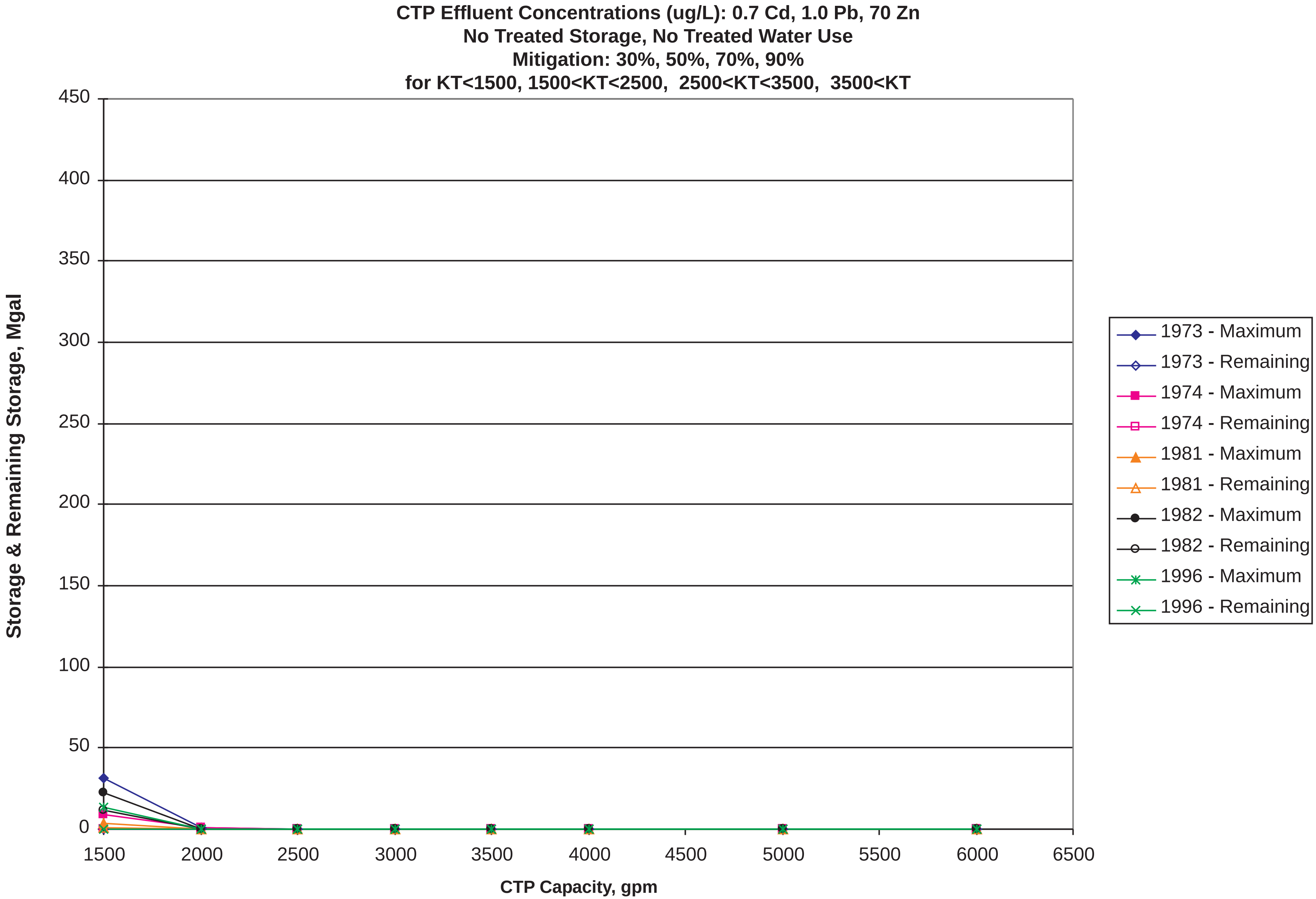

FIGURE 4-12

REQUIRED AND REMAINING STORAGE VS. CTP CAPACITY (30%, 50%, 70%, 90% EFFECTIVE MITIGATIONS)

BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL

NEXT

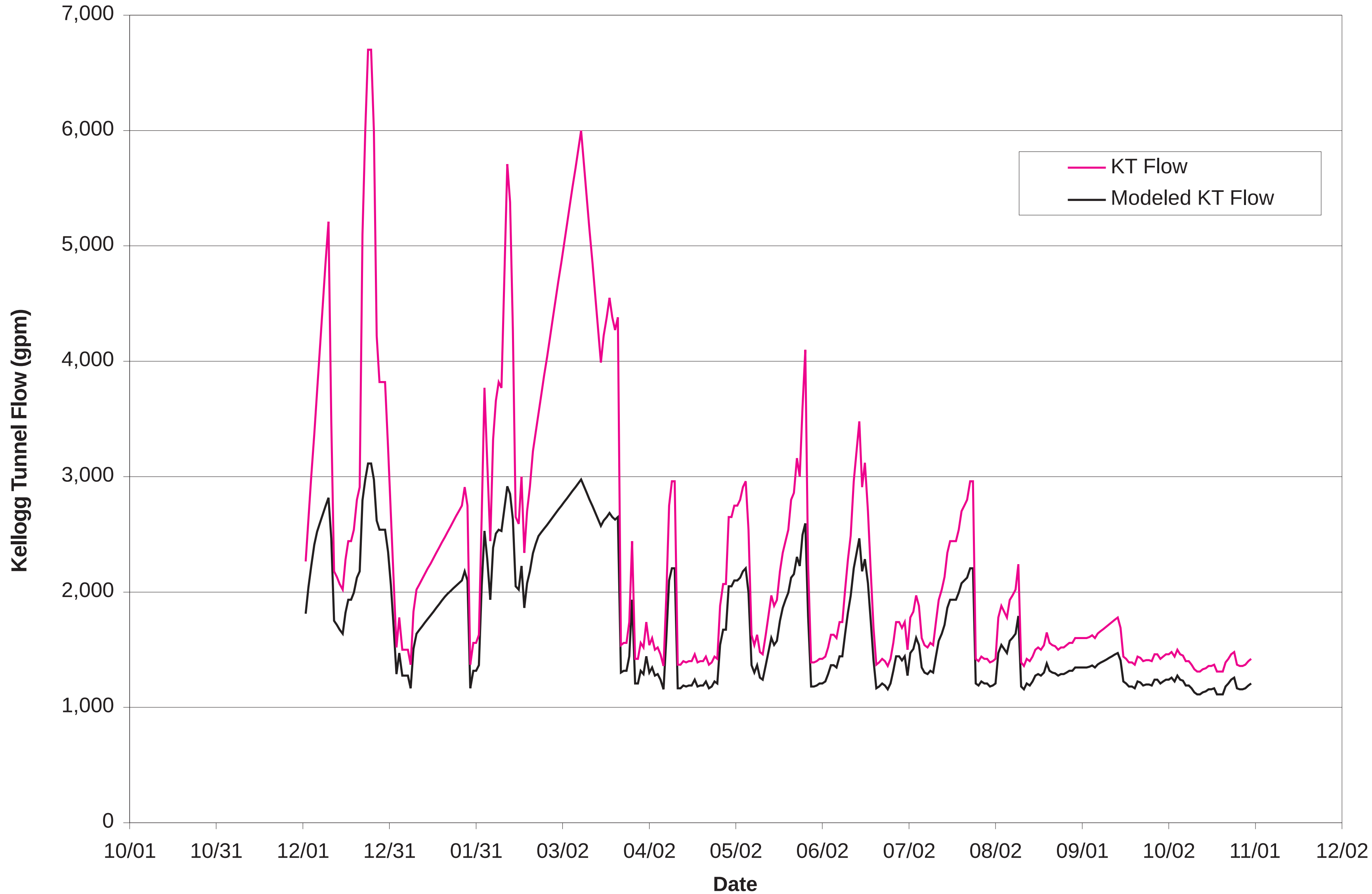

FIGURE 4-13

WATER YEAR 1973 KELLOGG TUNNEL HYDROGRAPH COMPARED TO A MODELED FLOW REDUCTION OF 15, 30, 50, 80%

BUNKER HILL MINE WATER MANAGEMENT RI/FS

CH2MHILL

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